

Between hosts and neighbours: The regional dynamics of the Winter Olympic Games

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The Olympic Games are considered to be among the most significant sporting competitions in the world, attracting a great deal of sponsors and the participation of many countries. In this article, we analyse country-specific successes in the Winter Olympics between 1960 and 2018. Several studies have documented the impact of various macroeconomic factors on countries' success in both the Summer and Winter Games. In addition, the host effect has been connected to medal success, although it is not known how hosting the Games contributes to the long-term success of the host country itself or its neighbouring countries. Thus, our study contributes to the existing literature by using data from 1960 to 2018, studying it with panel analysis and paying particular attention to the duration of the host country and neighbour effect on success in the Winter Olympics. In the panel analysis, after taking account of country fixed effects, the host effect was positive only during ongoing Games. Furthermore, we found an increasing time trend, albeit not unanimously statistically significant, related to the neighbour effect.

Keywords: Winter Olympic Games; hosting Games; neighbour effect: success

Subject classification codes: Z20, L83, H50.

Introduction

Medals at the Winter Olympics have become increasingly difficult because the amount of athletes, events and nations¹ participating has risen over the years. There exist many papers analysing medal success in the Olympics, but they mainly include only the Summer Games. Kuper and Sterken (2001) modelled the winning of Summer Olympic medals as a function of income, participation rate, legal system and home advantage. They also provided a methodology and predictions for medal success in the 2002 Winter Olympic Games. They modelled medal winning as a proportion of total medals available and total participation. Predictions of medal wins were generated based on their estimated participation predictions, along with host country status, per capita income, and numerous dummy variables for various sub-groups in different countries based on their legal systems.

Different macroeconomic factors (e.g. GDP and population) have been shown to explain success in the Summer and Winter Olympics (Van Bottenburg, 2000; Riordan, 1993, 2002; Johnson & Ali, 2000; Bernard & Busse, 2004; Johnson & Ali, 2004; Mitchell & Stewart, 2007). Thus, our study explores standard macroeconomic factors that could affect success in the Winter Olympics. Moreover, it contributes to and expands upon the existing literature by analysing the host effect and neighbour effect on success Winter Olympics not just during ongoing Olympic Games but also for the eight years before and after them. While the host effect in explaining success in the Summer Olympics has been widely documented in previous literature (Bernard & Busse, 2004; Shibli et al., 2012; Rewilak, 2021; Vagenas & Vlachokyriakou, 2012; Kari et al., 2022), it is currently unknown how many years before and after the hosting of the Games that the host effect can be observed in the Winter Olympics. The same applies even more clearly to the neighbour effect. Johnson and Ali (2004) argued that

¹ Technically it is individual cities which host the Olympic Games (within nations)

neighbouring countries benefit at least from lower transport costs and familiar climate factors as well as favourable training conditions, creating a similar advantage to that enjoyed by the host country, compared with other visiting countries, in the Olympics.

Our study extends the existing literature by capturing the Winter Olympic Games held from 1924 to 2022. Such a long time series is used in descriptive tables and figures. The econometric modelling used in this paper covers the Games organised between 1960 and 2018. The use of a wider time series is prevented by the availability of macro data. We extended our research over a longer period to avoid potential contingencies in the success of the Winter Olympics. As a result, the data we used in the study contained observations from 37 countries (Appendix 1), and there were 267 observations in our regressions. This article offers a new and current perspective to the literature by examining Winter Olympic success using panel analysis.

To preview our most important findings, we found that experience as a Games organiser, GDP and population positively related to success in the Winter Olympics. In particular, being host country can be considered a positive factor in explaining the number of medals. However, after taking into account country-level fixed effects, our preferred panel data results showed that the positive connection between hosting the Games and success in Winter Olympics concerned only ongoing Games.

This paper provides a new and timely perspective on the literature on Winter Olympic success by examining potential factors to help explain the Olympic success over the past six decades. The rest of the paper is organised as follows. The following section discusses the earlier literature concerning success in the Winter Olympic Games. Next, the data and descriptive statistics are presented, after which the empirical results are described. The last part presents the conclusions and a discussion of the possible implications and limitations of our study.

The literature review

Early literature on Olympic success includes those of Ball (1972), Levine (1974) and Grimes et al. (1974). Later Bernard and Busse (2004) helped revitalize the literature by developing a theoretical and empirical basis for predicting the number of medals a country will win. Nevertheless, their study only considered the Summer Olympic Games. Their model showed that greater economic resources and an increased population lead to a greater amount of medals due to and the improved health and sports infrastructure and greater talent pool. They found also that host countries tend to win more medals, that planned (and Soviet) economies are more successful, and that the time required to build sports infrastructure is reflected in delayed medal wins. A greater economic strength helps provide resources for athletic training and success, and a larger population provide a wider potential pool of athletes.

Rewilak (2021) challenges the long-standing assumption in the Olympic economics literature, originating from Bernard and Busse (2004), that GDP per capita consistently predicts Olympic success. Using more advanced econometric techniques such as Mundlak transformations to control for unobserved country heterogeneity, Rewilak demonstrates that the apparent GDP effect largely disappears once time-invariant national characteristics—such as culture, geography, and institutional quality—are properly accounted for. This finding implies that cross-sectional models may overstate the importance of economic resources by conflating them with deeper structural advantages.

Our panel results for the Winter Olympics partially supports this critique. While GDP remains positively associated with medal counts in OLS estimations, the effect slightly weakens once fixed country effects are included. This suggests that part of the GDP-medal relationship is driven by unobserved, time-invariant factors such as geographic conditions, sporting culture and institutional differences across countries. Fixed effect models account for these persistent national characteristics. However, unlike Rewilak (2021), we find that GDP

effect does not disappear entirely once fixed effects are included. This suggests that economic capacity continues to exert a modest but genuine influence over time. For instance, as increasing national wealth enables additional investments in sports infrastructure, coaching systems and athlete development. The divergence from Rewilak's results may reflect structural differences between the Winter and Summer Games, as winter sports depend more heavily on climatic conditions and long-term infrastructure commitments. The divergence from Rewilak's (2021) findings may stem from differences in data scope, model specification and temporal coverage. Rewilak (2021) focuses on the Summer Olympics 1996-2016 using panel Tobit model with a Mundlak correction and our analyses examines winter games 1994-2022 with standard panel regression. The smaller pool of participation nations in the Winter Olympics may amplify the role of economic resources. Also, absence of the Mundlak adjustment and the broader temporal span could partly explain why GDP retains statistical significance in our models.

In addition to macroeconomic factors, previous studies have documented that hosting the Winter Olympic Games itself is connected to improvements in performance (e.g., Bernard & Busse, 2004; Shibli et al., 2012; Rewilak, 2021; Vagenas & Vlachokyriakou, 2012). Bernard and Busse (2004) in turn showed that home-country advantage explained around 1.8% of the medal share. The home advantage seems to be partly related to the home crowd, which supports the home team. Wood and Meng (2021) estimated that the economic impact of the 2018 Winter Olympics was positive to the host country, South Korea. The contribution of the Games to national output was higher than their operational costs. Hosting Winter Olympics was therefore economically profitable.

Kuper and Sterken (2001) found that a host country's legal system may affect the success in the Summer Games. The legal system is connected to that countries can be more selective in sending athletes, which results in a higher average team quality. Kuper and Sterken

(2001) included GDP per capita as an additional factor in their country-specific regressions to show the higher average quality of a national² team. They also included a public media variable and televisions per capita, from the Rome 1960 to the Barcelona 1992 Summer Olympics to indicate public media pressure on sports performance.

Pfau (2006) used economic and demographic characteristics for determining Winter Olympics' success. In the paper, the equivalent model to Bernard and Busse (2004) was applied, but it explained medal success in the Winter Games using data from the Winter Olympic Games between 1960 and 1998. Neither Kuper and Sterken (2001) nor Johnson and Ali (2004) included an independent variable for lagged medal totals, thereby missing the possibility having a proxy measure of existing sports infrastructure. Nevertheless, lagged medal shares were included in the models estimated by Phau (2006), Otamendi and Doncel (2014) and Andreff and Andreff (2011). In those analyses, they tested if past success generates momentum for future success too.

Johnson and Ali (2004) found host country status, GDP per capita, one-party or communist system and heavy winter climate explaining Olympic success. They found that, unlike in the Summer Olympic Games, population does not explain medal success, and that smaller countries may even have a small, albeit not statistically significant, advantage. They also included squared population size and GDP per capita as explanatory variables to test for potential non-linear effects. They did not find any non-linearities from the population variable but did identify that countries with higher income levels send disproportionately more athletes to Winter Games.

² Officially, the National Olympic Committees (NOCs) send the teams and are the entities represented at the Games. However, it is very common to speak of nations being represented.

The result implies that Olympic participation increases quadratically with national income. Nevertheless, higher income does not have any statistically significant explanatory power for explaining the medals won, according to Johnson and Ali (2004). Being a host nation has undeniably great benefits; nevertheless, the neighbouring nations do not share in the medal success in the Winter Games. Additionally, Balmer, Nevill and Williams (2001) found that several winter Olympic competitions have home advantages.

Climate is also important for the Winter Games. Colder nations outperform nations with a more pleasant climate, of which are examples by Scandinavia, Canada and Russia. Additionally, Johnson and Ali (2004) also included as an explanatory variable the number of medals available during the Games. While winning a medal has become more demanding over time (as the number of participants has increased), winning medals has on the other hand become easier because the number of medals available has increased. The increase in the number of medals and new sports introduced more than compensate for the increase in the number of participants. As stated by Johnson and Ali (2004), one-party and communist countries receive more medals.

Otamendi and Doncel (2014) used econometric modelling and indices of concentration to estimate and predict medal shares by country and sport. They also added a Herfindahl index for added robustness to their analysis. Also, according to their results, other factors related to success were geography and tradition.

Several economic determinants of Winter Olympic performance have been tested in the past, usually consisting of, for example, population and GDP per capita. Economic variables were linked to nutrition, mortality and weather in athletes' home nations. Later, in various studies until the 1970s, several variables were considered as possible factors of Olympic success, namely protein consumption, colonial past, newspaper supply, life expectancy, urban

population, geographical surface area, religion, military expenditure, judicial systems and sports taught at school (Andreff & Andreff, 2011).

During the Cold War, however, a significant new variable emerged, which was the country's political regime. The first Western work to attempt to explain relationship between medal winnings and a nation's political regime was Ball (1972), who differentiated communist and capitalist regimes. Further, the first two econometric analyses of the Olympics (Levine, 1974; Grimes et al., 1974) showed that communist countries were outliers by regressing medal wins on population and GDP per capita; these countries won more medals than their population and levels of economic development predicted.

The influence of the Olympic host country on medal wins has become an important explanatory variable. The host wins more medals than otherwise because the national athletes' stronger motivation when competing at home, a large number of national fans, has adapted to the local weather and may not be tired from the journey before the Games (Andreff & Andreff, 2011).

Andreff and Andreff (2011) tested whether there is a significant difference if the variable explained is the country-specific percentage of medals (medal share) or the absolute number of medals. No difference was found. In this paper, we use the absolute number of medals, as suggested by Andreff and Andreff (2011). The authors used an interesting approach when using economic well-being and population as regressors, they four-year lagged ($t-4$) both of these variables, assuming it would take that long to build up, train, prepare and make an Olympic team competitive in time.

In another innovation, Andreff and Andreff (2011) included a variable in the model to describe each nation's winter sports facilities and resorts. They used data on the absolute amount of winter sports facilities and ski resorts in the countries. While this represents an important attempt to quantify winter sports infrastructure, the measure may not fully capture its functional

relevance across countries. For example, Finland (with a long tradition of skiing lifestyle) is categorised as having only an average number of ski facilities. A more informative approach might involve adjusting for population size for instance by using facilities per capita. Our fixed effect (FE) panel model helps address some of these limitations by controlling for unobserved, time-invariant country characteristics such as culture, climate, and long-standing winter sports traditions, thereby accounting for persistent cross-country differences in infrastructure. However, it does not capture time-varying developments, such as new investments in training facilities, which may bias results if correlated with medal success. Future research could therefore consider per capita or climate-adjusted indicators to more accurately represent countries' winter sports capacity.

As suggested by Kari, Mangeloja and Tohmo (2022), military expenditure is a useful addition for explaining Olympic success. Military expenses are a proxy for political strength and for communist regimes, which could also contain explanatory power for Winter Games. Life expectancy, fertility or other health-related variables are commonly used in models explaining Summer Games but have been absent in Winter Games analysis. It might be logical to assume that a nation's health status could affect sports competitions, including Winter Games.

Matthias Firgo's paper, "The causal economic effects of Olympic Games on host regions," investigates the economic impact of hosting the Olympics on host areas. He found that Winter Olympics produce negative regional economic effects unlike Summer Games. His findings reveal that the Summer Olympics temporarily boost a region's GDP by about 3–4 percentage points relative to the national level during the event year and the preceding year. While there's some evidence of positive long-term effects, the results are not statistically robust. In contrast, Firgo's study finds that the Winter Olympics do not have a positive economic

impact on host regions. Instead, they can lead to a temporary decline in regional GDP per capita in the years surrounding the event.

The article "The less obvious effect of hosting the Olympics on sporting performance" by Gergely Csurilla and Imre Fertő examines host country success at the Summer Olympics (1996–2021). Their findings challenge the common belief in a host-country advantage in medal performance. When they controlled for socioeconomic variables, the host effect largely disappeared. According to the authors, the increase in medals associated with hosting is less evident than often suggested in literature or public discourse.

Haifeng Li's paper, "The Evaluation, Constraints and Impacts of Beijing 2022 Winter Olympic Games on China's Socio-Economic Development," analyses the effects of the Beijing 2022 Winter Olympics on China's socioeconomic development. He found that the GDP effects are about twice as strong for the Winter Olympics compared with the Summer Games. The study posits that hosting the Olympics is a "training exercise" that tests a country's social governance, organizational efficiency, and corporate capacity. The article emphasizes that a flourishing and progressive country is a necessary prerequisite for hosting the Games, suggesting that positive outcomes depend on an already solid foundation.

For the data used, it's assumed that the International Olympic Committee website has the latest medal updates, taking into account subsequent disqualifications and other issues. GDP and population data came mainly from the World Bank's World Development Indicators.

Data

The main aim of our study is to analyse Winter Olympic success by empirically testing whether the host effect, together with various macroeconomic variables, is connected to a country's ability to win medals at the Winter Olympics. Our data include observations from 37 countries (Appendix 1) between 1924 and 2022, and the number of observations in our regression

analyses was 267 (for the years 1960–2018). The main variables used to explain Olympic success were GDP per capita, population, fertility, hosting of the Olympics and neighbourhood of the organising country (Table 1).

Table 1. Definitions of dependent and independent variables used in the empirical analysis

Variable	Definition
Total_medals _{it}	The dependent variable, the amount of medals won in Winter Olympic Games by country <i>i</i> at year <i>t</i> .
Gold _{it}	The dependent variable, the amount of gold medals won in Winter Olympic Games by country <i>i</i> at year <i>t</i> .
Silver _{it}	The dependent variable, the amount of silver medals won in Winter Olympic Games by country <i>i</i> at year <i>t</i> .
Bronze _{it}	The dependent variable, the amount of bronze medals won in Winter Olympic Games by country <i>i</i> at year <i>t</i> .
GDP per capita	Country's GDP per capita (constant 2015 US\$; Thousand).
Population	Country's total population (million).
Fertility	Fertility rate, total (births per woman)
HOST ₋₂	Equals one 8 years before hosting an Winter Olympic Games, and zero if otherwise
HOST ₋₁	Equals one 4 years before hosting an Winter Olympic Games, and zero if otherwise.
HOST _{ongoing}	Country hosting ongoing Olympic Games. 1 = If a country hosts ongoing Olympic Games. 0 = Otherwise.
HOST ₊₁	Equals one 4 years after hosting an Winter Olympic Games, and zero if otherwise.
HOST ₊₂	Equals one 8 years after hosting an Winter Olympic Games, and zero if otherwise.
Neighbour-2	Equals one if the country is a neighbor of the Winter Olympic host country (8 years before the Games), and zero otherwise
Neighbour-1	Equals one if the country is a neighbor of the Winter Olympic host country (4 years before the Games), and zero otherwise
NEIGHBOUR _{ongoing}	Country is a neighbor of the Winter Olympic host country. 1 = If a country is a neighbor of the ongoing Olympic Games host country. 0 = Otherwise.
Neighbour ₊₁	Equals one if the country is a neighbor of the Winter Olympic host country (4 years after the Games), and zero otherwise.
Neighbour ₊₂	Equals one if the country is a neighbor of the Winter Olympic host country (8 years after the Games), and zero otherwise.

Table 2 shows the main features of the Winter Olympics during the review period.

Table 2. Characteristics of the Winter Olympic Games (1924–2022)

Year	Host	Nations	Events	Sports	Athletes, in total	Male	Female
1924	Chamonix	16	16	6	258	247	11
1928	St. Moritz	25	14	4	464	438	26
1932	Lake Placid	17	14	4	252	231	21
1936	Garmisch- Partenkirchen	28	17	4	646	566	80
1948	St. Moritz	28	22	4	669	592	77
1952	Oslo	30	22	4	694	585	109
1956	Cortina d'Ampezzo	32	24	4	821	687	134
1960	Squaw Valley	30	27	4	665	521	144
1964	Innsbruck	36	34	6	1091	892	199
1968	Grenoble	37	35	6	1158	947	211
1972	Sapporo	35	35	6	1006	801	205
1976	Innsbruck	37	37	6	1123	892	231
1980	Lake Placid	37	38	6	1072	840	232
1984	Sarajevo	49	39	6	1272	998	274
1988	Calgary	57	46	6	1423	1122	301
1992	Albertville	64	57	6	1801	1313	488
1994	Lillehammer	67	61	6	1737	1215	522
1998	Nagano	72	68	7	2176	1389	787
2002	Salt Lake City	78	78	7	2399	1513	886
2006	Turin	80	84	7	2508	1548	960
2010	Vancouver	82	86	7	2566	1522	1044
2014	Sochi	88	98	7	2873	1714	1159
2018	Pyeongchang	92	102	7	2922	1680	1242
2022	Beijing	91	109	7	2871	1556	1315
Average		50	48	6	1436	992	444

An important takeaway is that the amount of participating athletes, events and countries has steadily increased since the Chamonix 1924 Winter Olympic Games. Furthermore, the number of different sports has been nearly constant over the same period (Figures 1 and 2).

Figure 1. Nations, events and sports in the Winter Olympic Games (1924–2022)

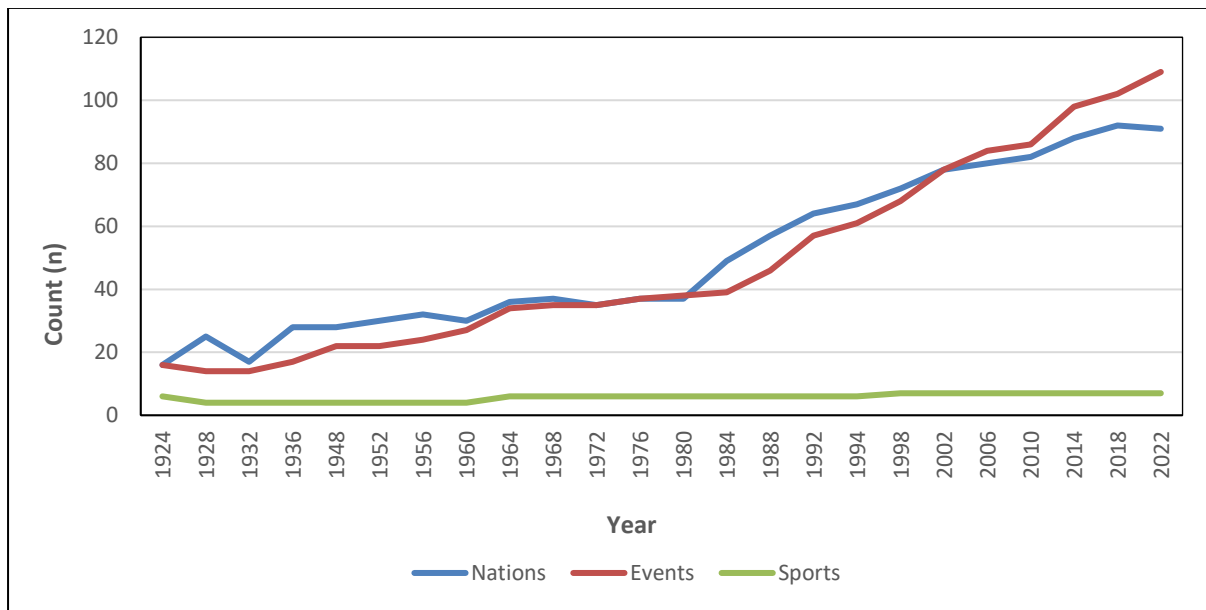
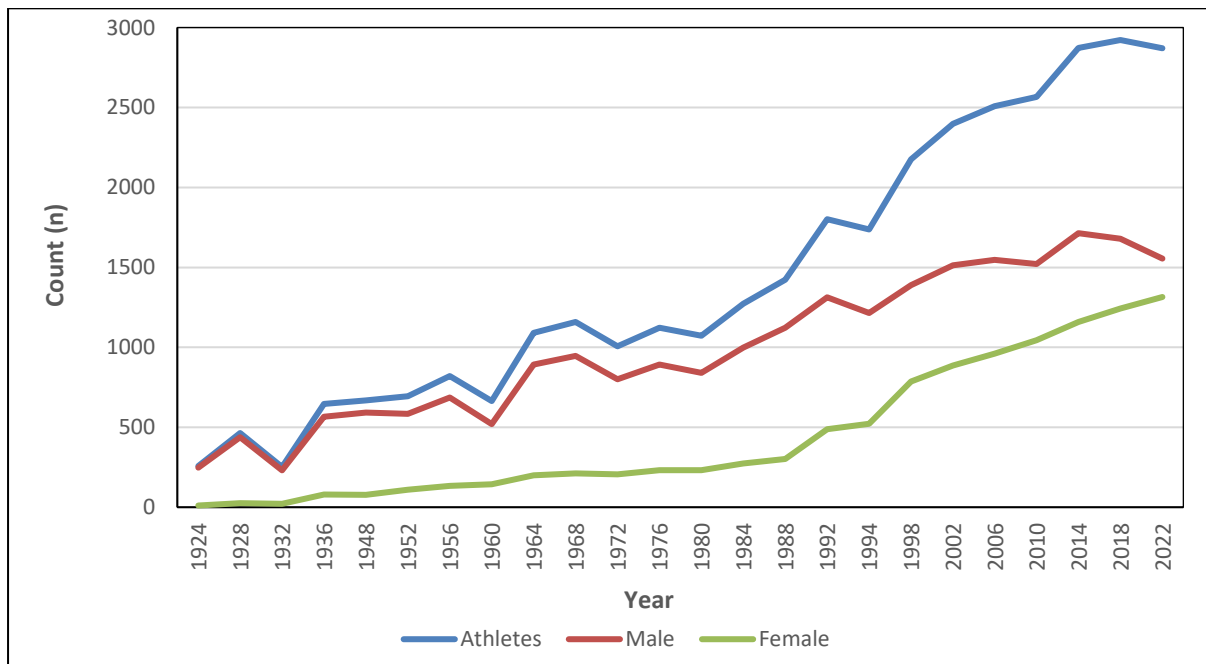


Figure 2. Athletes (male and female) in the Winter Olympic Games (1924–2022)



Thus, more nations and an increasing number of athletes are competing in the Winter Olympics than ever before for medals in nearly the same sports³. However, the number of disciplines has been growing steadily. The Winter Olympic Games can therefore be considered more of a global event that has economic, cultural and political effects throughout the world.

Figure 3. All-time medal winners in the Winter Olympic Games (1924–2022)

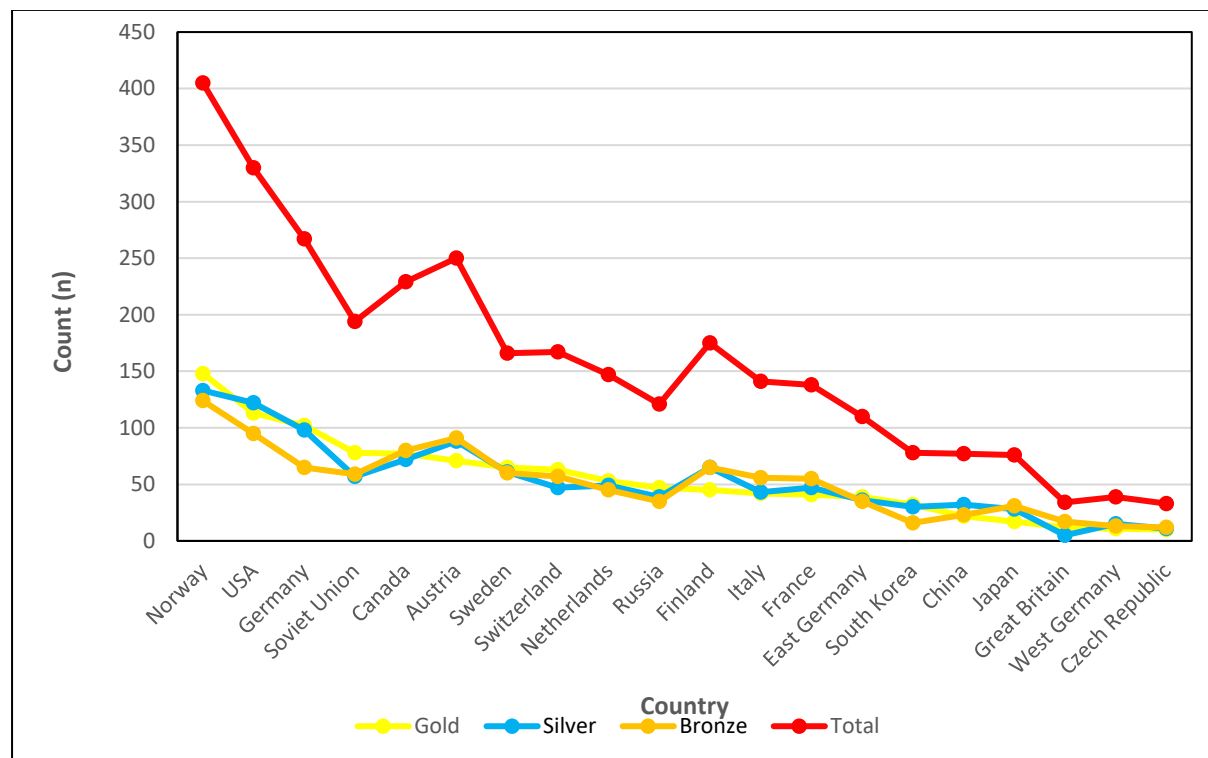
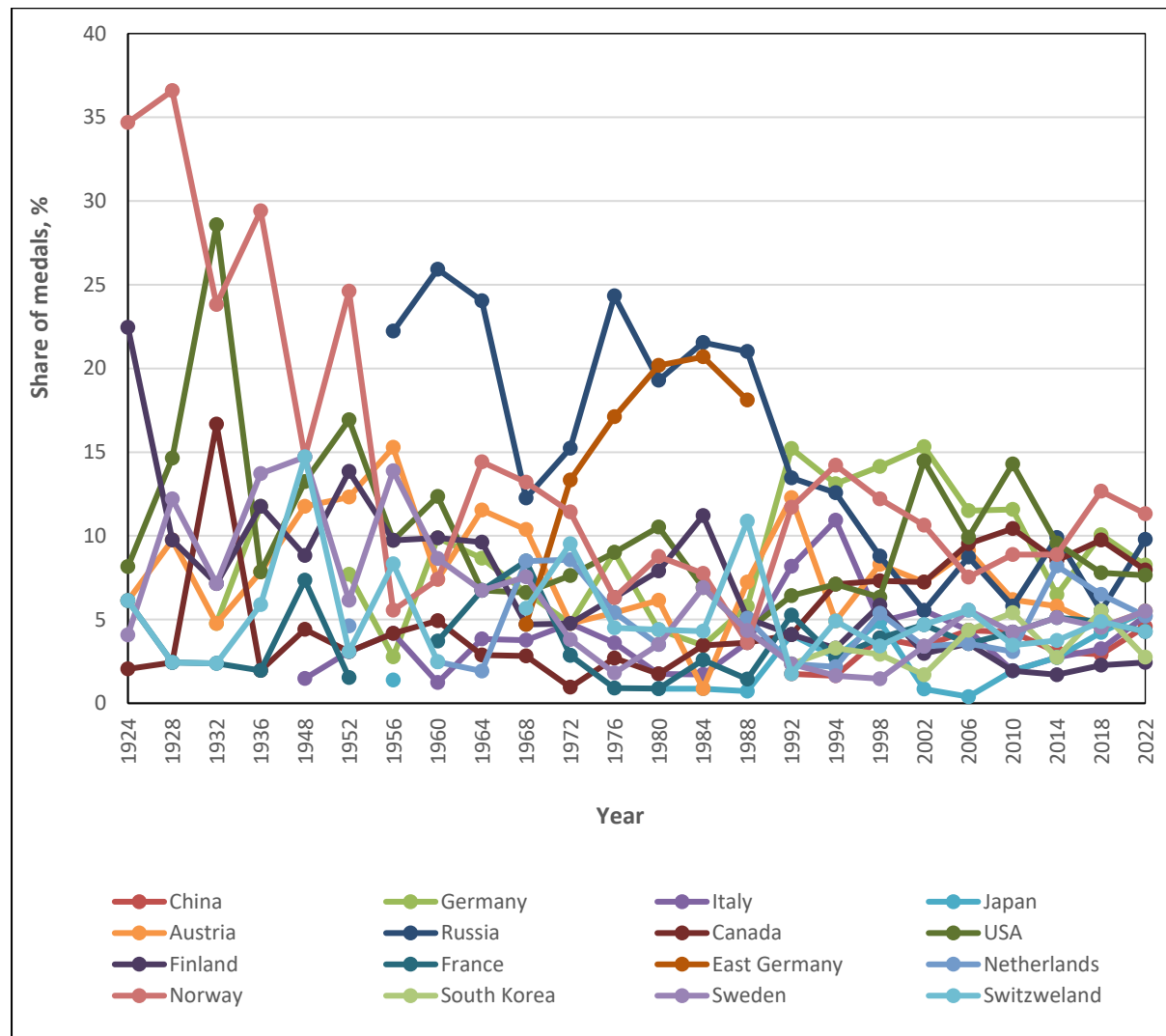


Figure 3 depicts the count of medals for the most successful nations (all-time medal winners) during the entire observation period of 1924–2022. Norway and the USA have dominated the winter Olympics since the beginning. Germany, Austria, Canada and the Soviet Union are the next most successful countries in the Winter Olympics. Sweden, Switzerland,

³ The sports in the Winter Olympics: alpine skiing, biathlon, bobsleigh, cross-country skiing, curling, figure skating, freestyle skiing, ice hockey, luge, Nordic combined, short track speed skating, skeleton, ski jumping, ski mountaineering, snowboarding and speed skating.

the Netherlands, Russia, Finland, Italy, Germany and East Germany have also been successful, as each of them has won a total of more than 100 Olympic medals at the Winter Games. It should be noted that East Germany and the Soviet Union are no longer competing for medals.

Figure 4. The share of medals of the most successful countries (1924–2022)



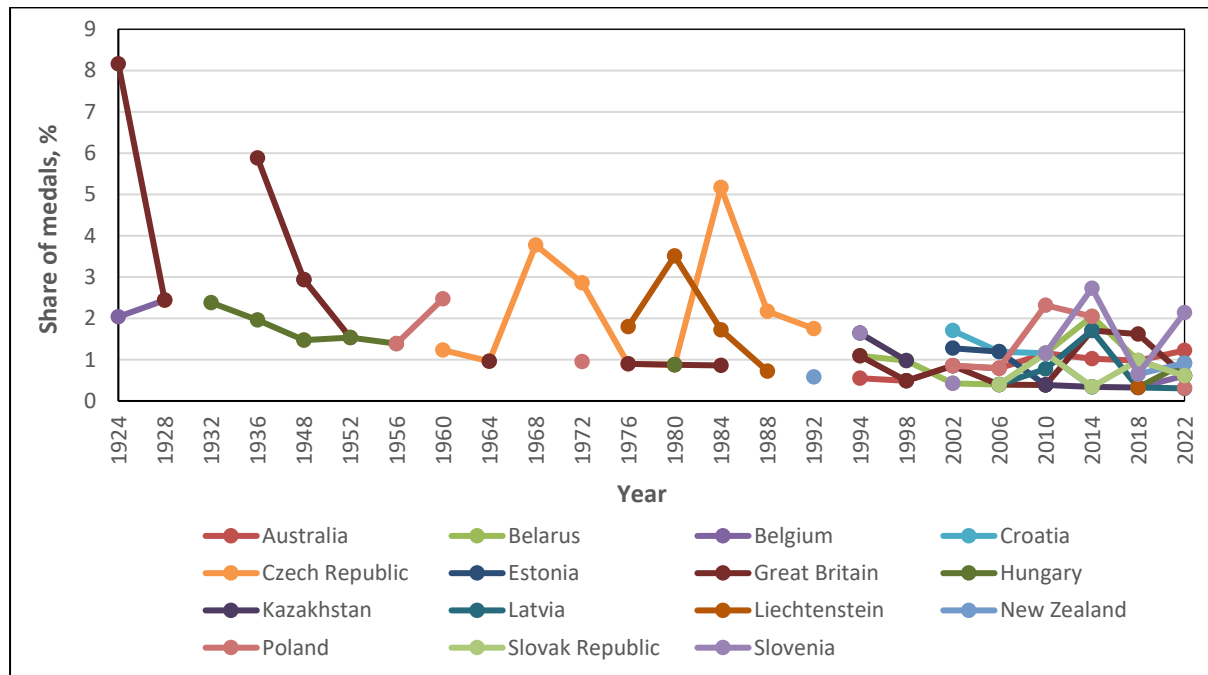
Note: Soviet Union (1956–1988), Commonwealth of independent states (1992), and Russia (1994–2022) have been combined as Russia; West Germany (1968–1988) and Germany (1992–2022) have been combined as Germany.

Figure 4 reveals the most successful countries medal share for each year (see also Appendices 2-4, where the same information is presented in tabular form). Norway was the most successful country in the Winter Olympic Games in the years 1924–1952. However, the USA was the most successful country in its own Winter Games in Lake Placid in 1932 (USA 12 medals vs Norway 10 medals). In addition, in the 1948 Games in St. Moritz, the USA almost reached Norway's medal count, ending only one medal behind.

Interestingly, Russia (the former Soviet Union) dominated the Olympics between 1956 and 1988. However, in 1968, Norway won 16 medals against the Soviet Union's 13 medals, reaching the top of the medal table. Moreover, East Germany started to succeed in the Winter Olympics in 1972, which led to the fact that in 1980, East Germany was the most successful country at the Lake Placid Winter Games. Since 1992, the competition for medals has been more even, although Norway and the USA have still mainly been the most successful winter sports countries. Interestingly, Germany has begun to challenge more and more the medal share won by the most successful nations over the observed years, having topped the medal table in 1992, 1998, 2002 and 2006. Russia has also done well, topping the medal table in 2014.

Figure 5 depicts nations that have won fewer medals at the Winter Olympic Games. Great Britain was successful in the early days of the Winter Olympics, for example winning Olympic gold in ice hockey in Garmisch-Partenkirchen 1936. From the end of the 1960s to the beginning of the 1990s, Czechoslovakia did reasonably well, most notably achieving more than 5 percent of the medals in Sarajevo 1984. In the 2000s, Slovenia has risen to be a medallist again.

Figure 5. The share of medals of the least successful countries (1924–2022)



Note: Czech Republic (1998–2022), and Czechoslovakia (1928–1992) have been combined as Czech Republic

Earlier studies have found (see e.g. De Bosscher et al., 2008) that wealth and population together typically explain more than half of Olympic medal success. Figures 6 and 7 provide a graphical visualisation of the significant positive correlation between Olympic success and population size as well as GDP, respectively.

The right edge of Figure 6 shows observations about the USA. The population of the USA has been the second highest, and the country has won at least six medals and at most 37 medals in all the Winter Olympics it has participated (1960–2022). The USA won the most medals (37 in total) at the 2010 Vancouver Olympic Games in Canada. The USA was also very successful in the 2002 Winter Olympics it hosted at Salt Lake City, where it won a total of 34 medals. China started to see more success in the Winter Olympics in the 2000s, during which decade it averaged around 10 medals.

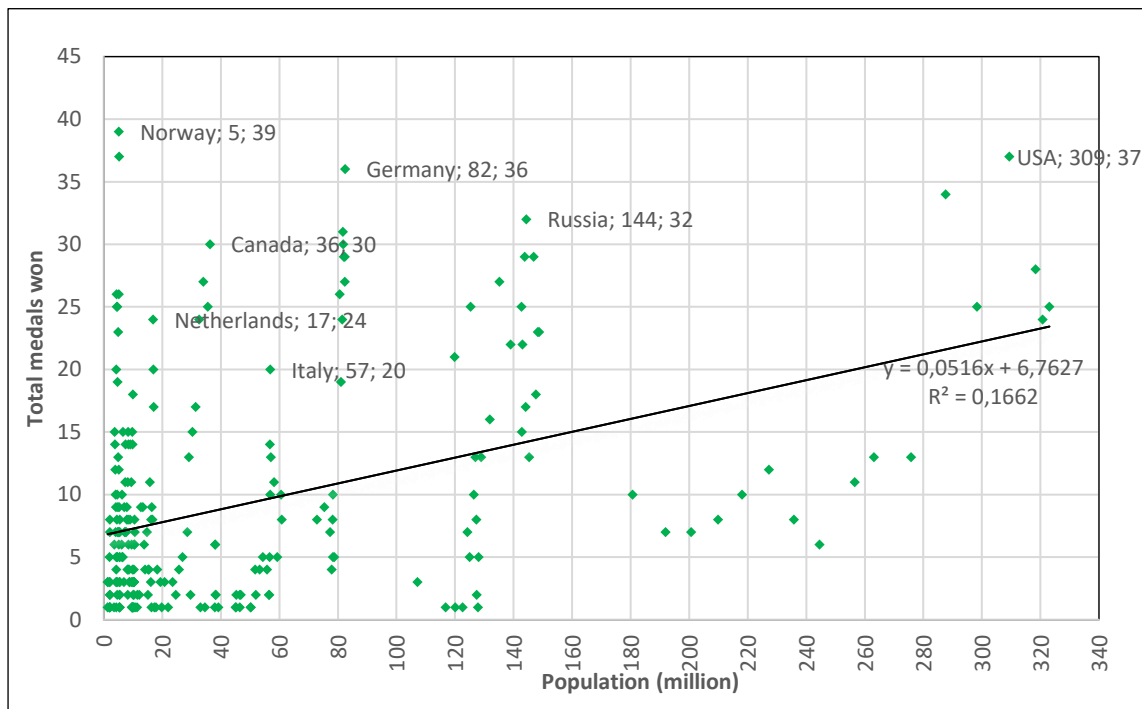
The highest observations on the left side of Figure 6 belong to Norway. Norway is a fairly small country in terms of population (4–5 million inhabitants during the review period),

but it has still been the most successful country in the Winter Olympics. Norway achieved its most medals at the 2018 Pyeongchang Games in South Korea (39 medals) and the Beijing Games in China (37 medals). Furthermore, Norway has been very successful in the Winter Olympics from 1992 onwards, winning at least 19 medals in each Olympics. After Norway, the highest numbers of medals on the left of the figure belong to Germany, Canada, Italy and the Netherlands. Between 1960 and 2022, Germany (population 73–82 million), Canada (18–36 million), Italy (50–61 million) and the Netherlands (11–17 million) won 8–31, 1–30, 1–20 and 2–24 medals, respectively.

Our data covers the Winter Olympic Games held between 1994 and 2022 for Russia; in those games, Russia won between 13 and 32 medals and achieved its most medals at the 2022 Beijing Games (32 medals) and 2014 Sochi Games (29 medals). Moreover, the Soviet Union won a minimum of 13 medals at each of the Games held between 1960 to 1992 and achieved its most medals at the 1988 Calgary Games (29 medals). The Soviet Union was also the most successful country in the Winter Olympic Games from 1956 to 1980 and in 1988.

East Germany won a large amount of medals (5–25 in each Games) between 1968 and 1988, but we could not include it in our data due to missing macro variables.

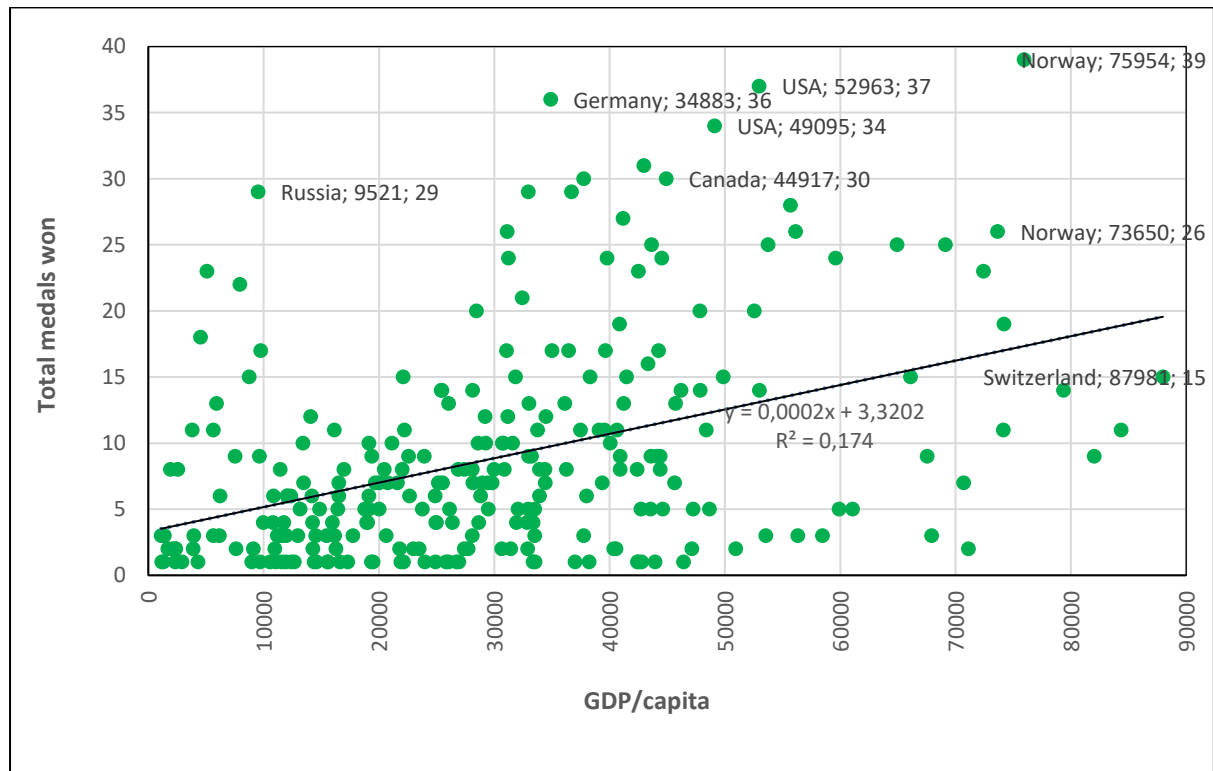
Figure 6. Population and total medals won in the Winter Olympic Games (1960–2022)



Note: The China population contains very large observations, and in this figure the values of China have therefore been left out. Thus, we can make the connection between other countries in terms of medal success more visible.

The middle of Figure 7 shows that the highest number of medals belongs to USA, Germany and Canada, which have GDP per capita ranging from US\$17,551 to US\$52,534 (USA), US\$34,131 to US\$46,168 (Germany) and US\$17,862 to US\$50,407 (Canada). The Norwegian and Switzerland findings are at the right of Figure 7 on both sides of the regression line. Norway's GDP per capita is the highest, and it has been the most successful country in the Winter Olympic Games between 1960 and 2022. In our data, GDP/capita in Switzerland is the second highest, and the country has also been successful in Winter Olympics. The highest observations on the left side of Figure 7 are from Russia. Russia's GDP per capita between 1994 and 2022 ranged from US\$5,506 to US\$11,681.

Figure 7. GDP per capita and total medals won in the Winter Olympic Games (1960–2022)



Population and GDP are both positively related to Winter Olympic success, as shown in Figures 6 and 7. The regression coefficients of both independent variables are positive and statistically significant. As a result, the descriptive analysis suggests that GDP and population are factors that explain Winter Olympics success. Because these findings are in line with the previous literature, they encourage us to analyse more macroeconomic factors that affect the medals count in the Winter Olympics.

Methods

In our study the explanatory variable was the number of medals won in the Winter Olympics. The macroeconomic variables used in our analysis were drawn from World Bank Open Data

(DataBank, World Development Indicators)⁴. The main aim of the analysis was to analyse whether the host effect, together with various macroeconomic variables, is connected with success in the Winter Olympics. Additionally, we analysed if the host effect has the shape of an inverted U-curve, which Kari et al. (2022) found in connection with the Summer Games.

First we employed the following OLS model:

$$y_i = \alpha + \beta_1 X1_i + \beta_2 X2_i + \beta_3 X3_i + \beta_4 X4_i + \beta_5 X5_i + \beta_6 X6_i + \beta_7 X7_i + \beta_8 X8_i + \beta_9 X9_i + \beta_{10} X10_i + \beta_{11} X11_i + \beta_{12} X12_i + \beta_{13} X13_i + \varepsilon_i,$$

where the dependent variable y_i is the number of Winter Olympic Games medals won by country i , with total medals, gold medals, silver medals and bronze medals examined separately as distinct dependent variables. Independent variables $X1$ - $X3$ represent economic, demographic and geographic factors, namely GDP per capita, population and fertility. $X4$ - $X8$ are dummy variables that take the value 1 for 8 years before hosting, 4 years before hosting, the year of hosting, 4 years after hosting, and 8 years after hosting the Winter Olympic Games and zero otherwise. Similarly, the dummy variables $X9$ - $X13$ capture the neighbouring timing relative to hosting the Winter Olympic Games. Alpha denotes intercept and β -vectors denote regression coefficients of independent (explanatory) variables, respectively. Regression error term is denoted by ε_i . In linear regression analysis, the error term is assumed to be constant across all observations; the error is not correlated across all observations, and it follows a normal distribution.

⁴ Source: <https://databank.worldbank.org/source/world-development-indicators> (Accessed October 18, 2022).

Identification of the effects of hosting relies on the assumption that, conditional on used covariates, the timing of hosting is exogenous with respect to other unobserved determinants of medal performance. However, hosting decisions may be endogenous, as countries that anticipate stronger performance or have recently invested heavily in sports infrastructure may be more likely to host. If such unobserved factors are correlated with medal outcomes, the estimated coefficients on hosting-related variables could be biased.

After controlling for observable characteristics and timing dummies, there are no omitted factors that simultaneously influence both the likelihood of hosting and medal outcomes.

To address this issue, we estimate a fixed effects (FE) panel model, which controls for country-specific, time-invariant factors such as culture and long-standing infrastructure. However, our model does not eliminate bias from time-varying unobserved factors such as investments in athlete development or changes in sports policy. As a consequence, the results should be interpreted cautiously.

GDP per capita was included in our model to represent economic factors. It is assumed that wealthier nations invest more in sports and also aim for success in elite competitions such as the Olympic Games. The population represents demographic explanatory variables. The country's population forms a critical mass whereby potential athletes are maturing. In general, population has been typically used as a common explanatory variable in contemporary economic analysis of Olympic success.

In the previous literature on Olympic success (Moosa & Smith, 2004; Vagenas & Vlachokyriakou, 2012), the health status of the population and health expenditures were also expected to influence a winning of the Olympic medals. Higher health status is associated with the probability of finding Olympic athletes among the population.

One of the main indicators used in the economic literature for national health status is fertility. Fertility has decreased in all developed countries during the past decades. Rather than

using health expenditure as an explanatory variable, we used fertility as a indicator for a nation's ability to invest in health-related activities and as an proxy of the general health level of the population (Krishna & Haglund, 2008).

In Becker's (1960) seminal work on the economics of fertility, the key empirical finding was the large, persistent and widespread decline in fertility rates throughout the demographic transition. Before industrialisation, women in most countries would give birth to an average of five or more children in their lifetime. Fertility rates continued to remain high during the first decades of industrialisation, at the beginning of the 10th century. Whereas the norm had been five or six children, more and more families then stopped after having two children. This decline in fertility accelerated simultaneously with the economic growth was picking up. Economic growth and fertility are related in that the birth rates determines population growth, which is in turn is the driver of economic growth fixed resources and capital accumulation models. More importantly, the central role of human capital in quantity–quality models of fertility has provided a connection between the economics of fertility and human capital–based economic growth models, since Lucas' original contribution (1988). Therefore, since then, the negative connection between economic well-being and fertility has been found in economic growth models (Barro & Becker, 1989).

Furthermore, ill health and nutrition may affect fertility and early childhood development—factors which have an impact on future sporting activities (Haddad et al., 2003; Krishna & Haglund, 2008). Traditionally, there has been a negative connection between fertility and income. Models (economic) based on the quality–quantity trade-off and a mother's time opportunity costs, were able to take these regularities into consideration. Therefore, fertility is expected to negatively affect Olympic success. Previous research on Winter Olympic medals has not considered fertility as an explanatory variable. Therefore, one of our contributions to this literature is to test the significance of fertility on Winter Olympic success.

The hosting of the Games was also included in our model, as it has been shown to be a significant factor in terms of Olympic success. More specifically, we have analysed the host effect on Winter Olympic success at home Games and in the eight years before and after. We formulated five dummy variables: HOST-2, HOST-1, HOSTongoing, HOST+1 and HOST+2. The dummy variable HOST-2 was used to indicate a country's status as an Olympic host and equalled one in the eight years prior to hosting the Olympics and zero otherwise. The dummy variable HOST-1 equalled one in the four years before the Winter Olympics were hosted and zero otherwise. The dummy variable HOSTongoing equalled one if the country hosted the ongoing Olympics and zero otherwise. The dummy variable HOST+1 matched one in the four years after hosting the Olympics and zero otherwise. Finally, the dummy variable HOST+2 matched one in the eight years after hosting the Winter Olympics and zero otherwise.

Being a neighbouring country to a host of the Winter Games was also included in our model to represent geographic factors. More specifically, we analysed the neighbour effect on Winter Olympic success at ongoing Games and in the eight years before and after. We formulated five dummy variables: NEIGHBOUR-2, NEIGHBOUR-1, NEIGHBOURongoing, NEIGHBOUR+1 and NEIGHBOUR+2. The dummy variable NEIGHBOUR-2 was used to indicate a country's status as an Olympic host's neighbour and equalled one in the eight years prior to the Olympics and zero otherwise. The dummy variable NEIGHBOUR-1 equalled one in the four years before being a neighbour to the host of the Winter Olympics and zero otherwise. The dummy variable NEIGHBOURongoing equalled one if the country was a neighbouring country to the host country of the ongoing Olympics and zero otherwise. The dummy variable NEIGHBOUR+1 matched one in the four years after being a neighbour to the host of the Olympics and zero otherwise. Finally, the dummy variable NEIGHBOUR+2 matched one in the eight years after being a neighbour to the host of the Winter Olympics and zero otherwise.

Regression analysis is a commonly used method to analyse the connection between two or more variables. Ordinary least squares (OLS) is a standard method when there are more equations than unknowns. The idea is to analyse linear connections between at least one independent variable and one dependent variable. However, in our data, there were plenty of observations of the dependent variable at zero (the distribution is discrete for values greater than zero). In such skewed situations, many researchers tend to use Tobit models. As a consequence, a Tobit analysis was also performed in the present study as an additional analysis. Tobit models are regression models in which the range of the outcome variable is censored (Wooldridge, 2002), and the Tobit model used was a linear regression model, where the outcome variable was either left- or right-censored. With left-censoring, all values below some thresholds are censored (Rewilak, 2021), while right-censoring means that all the values above some thresholds take the threshold value.

Since the same countries were observed across multiple Winter Olympic Games between 1960 and 2018, panel methods are more suitable for analysing the data than cross-sectional approaches. Panel models allow us to control for time-invariant country-specific factors and thus reduce omitted variable bias. If substantial differences between OLS and panel estimates exist, this highlights the advantages of panel techniques and indicates that they provide more reliable and consistent results for longitudinal data.

Results

Table 3 shows the estimation results of our OLS regressions. We analysed separately the factors connected to the total number of medals and gold, silver and bronze medals won in the Winter Olympic Games between 1960 and 2018. The aim was to find out whether the factors explaining the success differed with regard to the colour of the medal (gold, silver or bronze). However, we did not notice any differences concerning the colour of the medal.

Consistent with previous research, we found that economic and demographic factors were associated with each country's number of medals won in Winter Olympics between 1960 and 2018. Specifically, our research found that economic factors measured by GDP per capita and demographic factors measured by population size were positively correlated with success in the Winter Olympics. Higher GDP may be related to the fact that more funding is directed to Olympic sports. Financial resources are an important factor in modern competitive sports, as funding is needed to train professional athletes and to build and maintain physical facilities such as stadiums and training camps. In terms of population, it is good to keep in mind that not everyone can physically or mentally develop their skills to reach the Olympic level. Therefore, a nation with a larger population may have a higher probability of finding individuals with the appropriate talent to win medals at the Winter Olympics.

Table 3 also shows that fertility was negatively correlated with Winter Olympic success. Increased economic well-being might have caused a drop in fertility in developed countries. As the same rich nations have won more medals in the Winter Olympics, it was according to our preliminary assumptions that the co-efficient for fertility would be negative. In particular, the fertility co-efficient was strongly statistically significant for the total amount of medals won, as seen in Tables 3 and 5.

Table 3. Estimation results for Winter Olympic medal regressions, OLS regression

Dependent variable: The amount of the medals won in Olympic games by a country i at year t				
	Total medals	Gold medals	Silver medals	Bronze medals
GDP per cap 1000€	0.193*** (0.029)	0.070*** (0.012)	0.060*** (0.011)	0.062*** (0.010)
Population (million)	0.006*** (0.001)	0.001 (0.001)	0.003*** (0.001)	0.002*** (0.001)
Fertility	-1.985** (0.780)	-0.761** (0.325)	-0.569* (0.323)	-0.654** (0.287)
Host ₋₂	1.921 (1.919)	0.594 (0.887)	0.574 (0.587)	0.753 (0.728)
Host ₋₁	2.319 (1.660)	0.678 (0.625)	0.919 (0.666)	0.723 (0.624)
Host _{ongoing}	8.083*** (2.296)	3.656*** (0.956)	2.672*** (0.994)	1.754 ** (0.736)
Host ₊₁	3.519* (2.123)	1.019 (0.901)	1.464* (0.883)	1.036 (0.710)
Host ₊₂	2.077 (2.621)	0.413 (1.012)	0.526 (0.967)	1.138 (0.953)
Neighbour ₋₂	-1.370 (1.429)	-0.691 (0.592)	-0.751 (0.555)	0.072 (0.618)
Neighbour ₋₁	-0.698 (1.055)	-0.407 (0.445)	-0.488 (0.428)	0.196 (0.481)
Neighbour _{ongoing}	0.178 (1.758)	0.596 (0.786)	-0.421 (0.612)	0.003 (0.546)
Neighbour ₊₁	1.390 (1.515)	0.561 (0.626)	0.430 (0.574)	0.399 (0.501)
Neighbour ₊₂	2.084 (1.538)	0.974 (0.675)	0.912 (0.553)	0.199 (0.581)
Constant	4.964** (1.741)	1.645** (0.730)	1.648** (0.688)	1.671*** (0.593)
R ²	0.273	0.242	0.217	0.234
F(13, 253)	7.53 ***	5.75 ***	5.77 ***	5.97 ***

Note: Inside parentheses robust standard errors. ***, **, * denote statistical significance at the 99%, 95%, and 90% levels of confidence. The number of observations in all regressions was 267 (n=267).

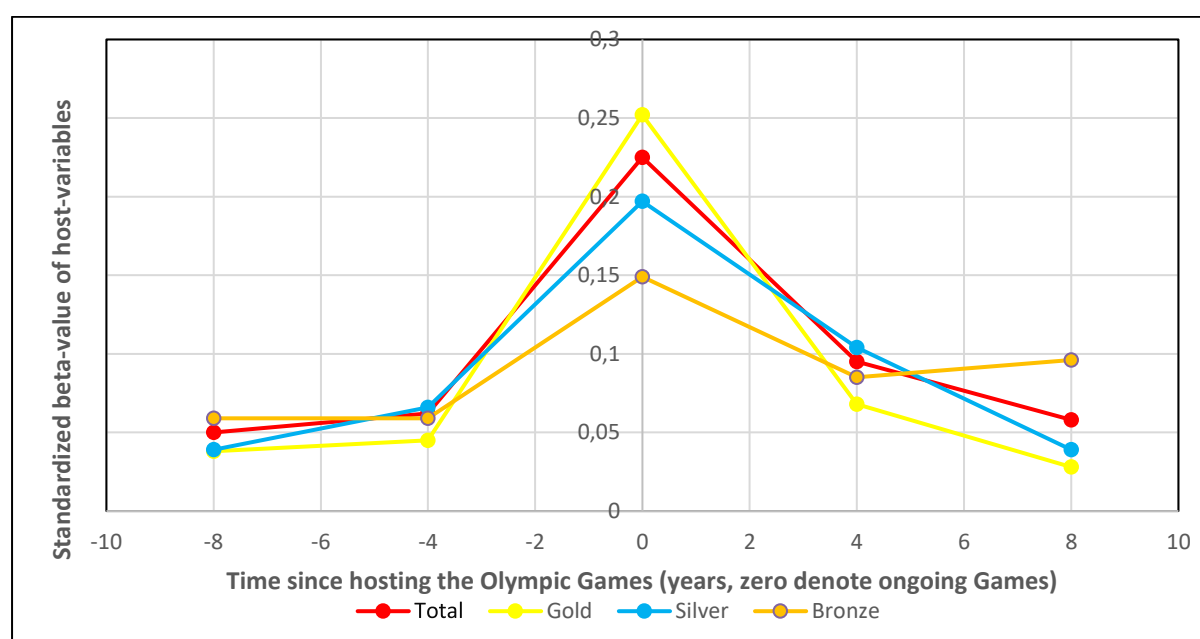
Similar to earlier studies (e.g. Bernard & Busse, 2004), our study suggests that home advantage was a positive and significant factor in explaining Olympic success (Table 3). As a result, being an Olympic host in the Winter Games increased the likelihood of winning medals, not only during the hosted Olympics but also at future Games. However, not all coefficients were statistically significant. For example, variables describing the time before the current Games were not statistically significant (host-1 and host-2)

A closer look at the host and neighbour effects shown in Table 4 and Figures 8 and 9 reveals interesting observations. First, the standardised estimation results shown in Table 4 show that the magnitude of the host effect of ongoing Games was the second highest after the GDP/capita variable. The effect was even stronger than the magnitude of the effect of population size. Second, Figure 8 depicts that the standardised beta values of the host variable start from a lower position on the y-axis of the graph eight years before the hosting of the Winter Olympics. The host effect peaks at the current Winter Games, and eight years after hosting the Games, the host effect descends back to its lower position on the y-axis. Moreover, part of the host coefficients were statistically significant. Thus, Table 4 and Figure 8 reveal an inverted U-shaped correlation between the host effect and Winter Olympic success.

Table 4. Estimation results for Winter Olympic medal regressions and standardised coefficients, OLS regression

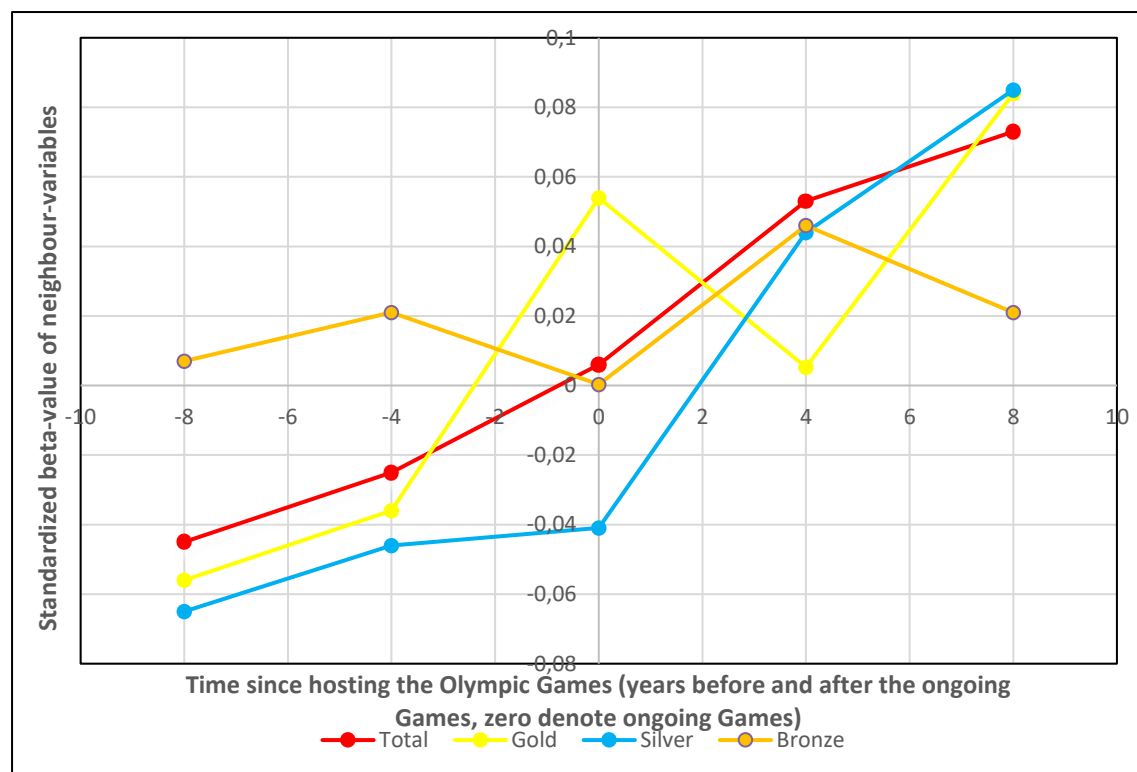
	Dependent variable: The amount of the medals won in Olympic games by a country i at year t			
	Total medals	Gold medals	Silver medals	Bronze medals
GDP per cap 1000€	0.434***	0.390***	0.359***	0.428***
Population (million)	0.156***	0.093**	0.192***	0.139***
Fertility	-0.111**	-0.105**	0.084*	-0.111**
Host ₋₂	0.050	0.038	0.039	0.059
Host ₋₁	0.062	0.045	0.066	0.059
Host _{ongoing}	0.225***	0.252***	0.197***	0.149**
Host ₊₁	0.095*	0.068	0.104*	0.085
Host ₊₂	0.058	0.028	0.039	0.096
Neighbour ₋₂	-0.045	-0.056	-0.065	0.007
Neighbour ₋₁	-0.025	-0.036	-0.046	0.021
Neighbour _{ongoing}	0.006	0.054	-0.041	0.0003
Neighbour ₊₁	0.053	0.053	0.044	0.046
Neighbour ₊₂	0.073	0.084	0.085	0.021
Constant	-	-	-	-

Note: Inside parentheses robust standard errors. ***, **, * denote statistical significance at the 99%, 95%, and 90% levels of confidence. The number of observations in all regressions was 267 (n=267).

Figure 8. Standardised coefficients for host variation

On the other hand, the neighbour effect cannot be seen in Table 4 and Figure 9. Moreover, neighbour coefficients were not statistically significant. Although Figure 9 illustrates some variation in the standardised beta values over time, these changes are not statistically significant over time. Figure 9 shows that the standardised beta value of the neighbour variable starts from a lower position on the y-axis of the graph eight years before the hosting of the Winter Olympics. However, the neighbour effect does not peak at the current Winter Games; rather, eight years after hosting the Games, the neighbour effect rises to its highest position on the y-axis.

Figure 9. Standardized coefficients for neighbour variation



Standardised beta-values of neighbour variables are presented in Figure 9, where the beta-values are plotted in relation to the hosting variable (in time). Thus, Figure 9 reveals a modest upward pattern in the neighbour effect, but the relationship with Winter Olympic Success is

weak and statistically inconsistent. At 10% significance level, gold medal counts show a marginally significant change, while silver medal counts differ significantly, comparing eight years before and after the Olympics ($F(1,253)=3.02, p=0.083$; $F(1,253)=4.14, p=0.043$). Other changes are not statistically significant, suggesting that there is no consistent evidence of a systematic neighbour effect on Winter Olympic performance.

Tobit analysis

The dependent variable in our data had a mass at zero, indicating that our data could be skewed in one direction. The skewness of the data can be used to justify the use of the Tobit model. Therefore, we also performed the analysis using Tobit models to examine the sensitivity of our OLS results and included the results of the Tobit models as an additional analysis. The likelihood ratio chi-square test (LR chi2 (13)) showed that at least one regression coefficient of the explanatory variable was not equal to zero⁵.

In sum, the Tobit regression results show that the coefficients and coefficient significance are consistent with our OLS results (Table 3). The Tobit analysis thus provided additional support for our OLS findings.

⁵ The contents of the parentheses indicate the degrees of freedom. This is defined by the number of predictors in the model.

Table 5. Estimation results for Winter Olympic medal regressions, Tobit model

	Dependent variable: The amount of the medals won in Winter Olympic games by a country i at year t			
	Total medals	Gold medals	Silver medals	Bronze medals
GDP per cap 1000€	0.193*** (0.024)	0.085*** (0.013)	0.071*** (0.011)	0.072*** (0.0096)
Population (million)	0.006*** (0.002)	0.002 (0.001)	0.003*** (0.0009)	0.02** (0.0008)
Fertility	-1.985** (0.969)	-0.675 (0.514)	-0.776 (0.471)	-0.879** (0.399)
Host ₋₂	1.921 (2.061)	0.850 (1.073)	0.777 (0.964)	1.074 (0.804)
Host ₋₁	2.319 (1.987)	1.271 (1.018)	1.190 (0.926)	0.956 (0.784)
Host _{ongoing}	8.083*** (1.926)	4.285*** (0.987)	3.091*** (0.896)	2.162 *** (0.754)
Host ₊₁	3.519* (2.014)	1.063 (1.074)	1.725* (0.942)	1.331* (0.791)
Host ₊₂	2.077 (1.918)	0.153 (1.031)	0.660 (0.909)	1.186 (0.765)
Neighbour ₋₂	-1.370 (1.619)	-1.066 (0.881)	-1.472* (0.812)	0.012 (0.648)
Neighbour ₋₁	-0.698 (1.504)	-0.840 (0.824)	-0.418 (0.712)	0.198 (0.602)
NEIGHBOUR _{ongoing}	0.178 (1.468)	0.701 (0.775)	-0.787 (0.717)	0.080 (0.582)
Neighbour ₊₁	1.390 (1.395)	0.759 (0.731)	0.248 (0.671)	0.404 (0.559)
Neighbour ₊₂	2.084 (1.523)	1.376* (0.787)	1.264* (0.712)	0.340 (0.600)
Constant	4.964** (1.958)	0.372 (1.053)	1.217 (0.945)	1.380* (0.796)
Left-censored	0	66	53	46
Right-censored	0	0	0	0
LR chi2 (13)	85.18 ***	68.85 ***	66.10 ***	71.70 ***

Note: Inside parentheses robust standard errors. ***, **, * denote statistical significance at the 99%, 95%, and 90% levels of confidence. The number of observations in all regressions was 267 (n=267).

A censored variable is a variable whose true value is unknown because the measurement process itself is able to report values only in a certain range. Our data did not include values that were wrongly stored as zeros; rather, we believe that zeros occurred in our data naturally because there were no censoring mechanisms to force the dependent variable values to appear as zeros. However, the distribution was skewed because the dependent variable contained many zeros. For OLS, this cannot be considered a serious problem, because OLS does not require normal errors to be consistent. Furthermore, Amore and Murtinu (2021) argued that if the residuals are non-normal and the variable to be explained has over the half of the censored observations, the Tobit model bias in small samples could be high. They also showed that the OLS regressions can be valid for non-normally distributed outcomes.

However, given the large proportion of zeros in Winter Olympic medal counts, standard OLS may be inadequate, as it does not explicitly account for the zero-inflated nature of the dependent variable. While the zeros are not due to censoring, the distributional mass at zero suggest that models designed for limited dependent variables such as Tobit or zero-inflated count models may better capture the underlying data-generating process. Using a Tobit specification allows for a more realistic treatment of the large number of zeros, providing a potentially more accurate representation of medal performance than OLS alone.

Endogeneity checking in OLS and Tobit analysis

A potential concern in our empirical analysis is the endogeneity of the variable capturing host-country status. Hosting the Olympic games may be correlated with unobserved factors affecting medal outcomes such as national sporting culture or political influence. To address this issue, we employed an instrumental variable approach to test for possible endogeneity in both OLS and Tobit analysis.

To assess the relevance of the proposed instrumental variable, we estimated a probit model where the dependent variable $HOST_{it}$ equals one if country i hosted the Winter Olympic Games. The key explanatory variable in the first-stage specification was the number of previous Olympic bids submitted by each country (Prior bids -variable), alongside a set of economic, demographic and geographic controls.

The coefficient on Prior bids -variable is positive and statistically significant at the 5 percent level ($z = 2.32$, $p = 0.020$). This suggests that countries that have applied more frequently in the past are more likely to host the Games. The implied F-statistics ($z^2 \approx 5.4$) indicates that the instrument is of moderate strength. Furthermore, the statistically significant association between past bidding activity and hosting status confirms that the instrument satisfies the basic relevance condition required for valid instrumental-variable estimation. The instrument is assumed to affect medal outcomes only through hosting. Past bidding behaviour is determined well before the Games and may reflect political and administrative decisions rather than athletic performance. Controls for economic, demographic and geographic factors help mitigate potential confounding, making it reasonable to treat prior bids as exogenous in instrumental variable analysis.

To test endogeneity, we applied a control function approach where the residuals from the first-stage probit were included in a linear regression of **total medals** on HOSTongoing and controls. The residuals are not statistically significant ($p = 0.704$) indicating no strong evidence of endogeneity. Prior bids -variable remain significant, supporting their use as an instrument. These results justify treating HOSTongoing as exogenous in subsequent instrumental variable analysis, while controlling economic, demographic and geographic factors.

We also evaluated the suitability of prior bids -variable as an instrument for hosting the Winter Olympic Games in relation to gold, silver and bronze medal outcomes. A linear regression of gold medals on HOSTongoing, prior bids and a set of controls indicates that the coefficient on prior bids -variable is positive but not statistically significant ($\beta = 0.222$, $p = 0.227$). The control function residuals are also not significant ($p = 0.318$) suggesting no strong evidence on endogeneity of HOSTongoing. Hostongoing-variable can be treated as exogenous. However prior bids -variable is a weak instrument for gold medals due to its lack of predictive power. Our results also show that prior bids is a strong and significant instrument for bronze medals and marginally relevant for silver medals. Control function tests indicate no evidence of endogeneity for HOSTongoing in silver or bronze medals.

We examined the potential endogeneity of the **HOST-1** dummy (four years prior to hosting) using bivariate probit model. Host-1 regressed on HOST-2 and controls, while HOST-2 regressed on the same set of covariates. The coefficient on HOST-2 in the HOST- 1 equation is not statistically significant ($p = 1$) and the estimated correlation between residuals (ρ) is effectively zero ($\rho = 0.998$, $p = 0.726$). This indicates no strong evidence of endogeneity.

These results suggest that the HOST-1 dummy representing four years prior hosting, can be treated as exogenous in OLS regression for total, gold, silver and bronze medal outcomes.

The post-hosting dummies (four and eight years after hosting are inherently predetermined relative to current outcomes. Under the assumption that future events cannot affect current performance, these variables are treated as exogenous in the analysis.

To test for potential endogeneity of HOSTongoing in the **Tobit model**, we included residuals from a first-stage probit of HOSTongoing as a control function. The residuals are not significant ($p = 0.473$) indicating no strong evidence of endogeneity. HOST's direct effect on medals is positive but not statistically significant. Prior bids -variable remain marginally significant ($p = 0.093$) supporting its relevance as an instrument. These results justify treating HOSTongoing as exogenous in subsequent Tobit analyses. Control function tests indicate no evidence of endogeneity for HOSTongoing. Therefore, HOSTongoing can be treated as exogenous in Tobit analyses for total, gold and silver or bronze medals.

We also tested the potential endogeneity of HOST-1 employing bivariate probit model with HOST-2 as a candidate instrument. First equation modeled HOST-1 as a function of HOST-2 and control variables. The second equation modeled HOST-2 as a function of the same controls. The correlation of the error terms (ρ) between the two equations was 0.998 but not statistically significant ($\chi^2(1) = 0.123$, $p = 0.73$). These results indicate that HOST-1 can be treated as exogenous. No instrumental variable correction or control function adjustment is necessary in subsequent Tobit models. Bivariate probit tests show no evidence of endogeneity for HOST-1. Therefore, HOST-1 can be treated as exogenous in Tobit analyses for total, gold,

silver and bronze medal outcomes without any instrumental variable correction or control function adjustment.

No convincing approach was found to whether the Host-2 (eight years before hosting) variable is endogenous.

Panel estimation

We estimated the link between success in Winter Olympic Games (medals won) and macro variables using the fixed effects method, which controls for all potential time-invariant heterogeneity across countries. We estimated the model separately for total medals, gold medals, silver medals and bronze medals won in Winter Olympic Games (Table 6).

The following model was used:

$$\text{Medals}_{it} = \beta_0 + \beta_1 \text{GDP}_{it} + \beta_2 \text{Population}_{it} + \beta_3 \text{Fertility}_{it} + \beta_4 (\text{Host}_{it}) + \beta_5 (\text{Neighbour}_{it}) + \varepsilon_{it}$$

where Medals_{it} denotes the medals won by the country i at time t . β :s are estimated coefficients of independent variables. The error term, ε_{it} , represents the way that the observed data differs from the actual population. The independent variables are shown in Table 1.

The model errors for the countries may have been correlated; as a consequence, the standard errors were clustered by country. Table 6 shows approximately 30%–47% of the variance of the dependent variable is explained by the model, which can be considered a good fit. For robustness checks, we also conducted panel regression estimations excluding Norway (Table 7) and both Norway and Russia (Table 8). We estimated separate models for total, gold, silver and bronze medals. The estimation results remain broadly consistent across all three model specifications. Both GDP per capita and population have positive and highly significant

effects across all models and medal categories confirming that economic wealth and population size consistently predict success in the Winter Olympics.

When Norway and later also Russia are excluded from the sample, some coefficient magnitudes decrease slightly, and a few variables lose statistical significance. This mainly reflects the strong influence of these exceptionally successful nations which act as outliers in the dataset. The smaller sample size also increases standard errors contributing to reduced significance levels.

The host and neighbour dummy variables retain broadly similar patterns although their effects become weaker once the top-performing countries are removed. Overall, the results demonstrate that the model's core relationships are stable and robust to alternative sample specifications.

Overall, our model was partly in line with the findings from previous literature. First, the model showed that home advantage was a significant factor in explaining Olympic success (e.g. Bernard & Busse, 2004; Shibli et al., 2012; Rewilak, 2001; Vagenas & Vlachokyriakou, 2012). Hosting an ongoing Winter Olympic Games had a positive sign and was statistically significant in panel regressions; however, the host effect was not statistically significant, or the sign turned negative before and after the ongoing Games. This finding is contrary to Kari et al.'s (2022) regression findings, according to which the organiser effect is positive and significant both before and after the ongoing Games. Second, Table 6 also shows that population and GDP per capita were connected with the success of Winter Olympics, as has been revealed in many studies concerning Summer Olympics' success.

The host effect differs markedly between the Winter and Summer Olympic Games due to structural, climatic, and economic factors. First, the Winter Olympics are smaller in scale, involving fewer sports, athletes, and participating nations, which amplifies the relative importance of local conditions such as snow, ice, and altitude. These factors disproportionately

benefit athletes accustomed to the host nation's climate and terrain, thereby intensifying short-term advantages but limiting broader diffusion effects observed in the Summer Games (Johnson & Ali, 2004). Second, Winter Olympic sports require highly specialized infrastructure—ski resorts, ice rinks, and sliding tracks—that are typically concentrated in wealthier or colder areas. Consequently, only a limited number of countries possess both the facilities and expertise to host, which constrains long-term spillovers and explains why the host advantage tends to dissipate quickly after the Games (Bernard & Busse, 2004).

Third, the economic legacy of hosting differs while Summer Olympics often yield temporary boosts in tourism and investment, research suggests that Winter Games can have neutral or even negative regional economic impacts (Firgo, 2021), reducing incentives for sustained sports development. Overall, after the Games, declining investments and a narrow participation base mean that the host effect in Winter Olympics reflects immediate environmental familiarity and logistical convenience rather than enduring institutional or athletic gains, in contrast to the broader and longer-lasting host benefits occasionally observed in the Summer Games.

In winter Olympics host advantage is real but short-lived because the underlying resources don't sustain continued performance once the immediate local and environmental benefits disappear.

We also tested the neighbour effect and found that the neighbour effect across the winter Olympic medal regressions (Tables 6-8) reveals that before the Games, neighbouring countries tend to perform worse than others, as indicated by negative and often statistically significant coefficients for variables 8 years and 4 years before the games. This suggest that proximity to the upcoming host may initially suppress success, possibly due to the concentration of sporting resources and attention within the host country itself. During the games, the negative neighbour effect remains present, especially for silver and bronze medals, although its significance varies

slightly across model specifications. After the Games, it seems that this negative effect vanished and even turned positive. For total medals, gold medals and silver medals, the coefficients turn positive unless typically not statistically significant 8 years after the games. Only the coefficients for 8 years after games turn positive and statistically significant for gold and silver medals in Winter Olympics models, where Norway or Russia are not included in the sample. Therefore, we cannot conclude that there is improvement in Olympic performance reflecting diffusion of Olympic enthusiasm, infrastructure investments, and training opportunities into the neighbouring countries.

It is interesting to note from Tables 6 that fertility was not negatively correlated with Olympic success. The panel estimation method with country-level fixed effects seems to have obliterated the effect of fertility found with less advanced statistical methods. Nevertheless, it may be that this phenomenon was not solely due to statistical properties. There exists an increasing amount of new economic literature noting that the income–fertility relationship is nowadays largely flat or even positive.

However, the reversal of fertility’s significance illustrates the value of panel estimation. While cross-sectional OLS might suggest a negative relationship between fertility and Olympic success, this correlation can be spurious due to omitted time-invariant country-specific factors, such as cultural attitudes towards sports or long-term investments in athlete development. By controlling for these factors in a panel setting, we find that fertility is not negatively associated with medal performance, highlighting why panel methods are crucial and demonstrating the potential pitfalls of simpler cross-sectional analyse.

As shown by Doepke et al. (2022), the economic impact of fertility has changed during this millennium. Recent work on the quantity–quality trade-off between fertility and economic well-being has argued that it is no longer evident in high-income countries. It seems that the connection between fertility and female labour force participation in different countries has

reversed. The relationship between fertility and women's education is no longer always weakened, even within countries. The trade-offs emphasised by these models still exist and are still important in explaining fertility behaviour in many contexts, including in lower-income countries. However, these trade-offs no longer cause large variation in the data for high-income countries (Doepke et al., 2022).

Previous models based on the opportunity cost of women's time argue that raising children leads to a lower rate of work for mothers in the labour market. Although, these opportunity costs still exist, they have diminished with the development of alternative forms of childcare. While someone other than the mother takes care of the childcare, the costs of children are no longer connected to the mother's opportunity cost of time. Doepke et al. (2022) pointed factors that help mothers combine a larger family with a career, namely the availability of public childcare or other supportive family policies, fathers' greater contributions to organizing childcare, social norms favouring working mothers, and a flexible labour markets. It may be that the extremely low fertility rates observed in many advanced economies have obliterated the effect of fertility on Olympic success.

In sum, after taking into account country-level fixed effects, our panel data estimations indicate that being an Olympic host for ongoing Winter Games increases the likelihood of winning medals. In addition, macro variables, population and GDP per capita were connected with success in the Winter Olympics.

Table 6. Estimation results for Winter Olympic medal panel regressions

	Dependent variable: The amount of the medals won in Olympic games by a country i at year t			
	Total medals	Gold medals	Silver medals	Bronze medals
GDP per cap 1000€	0.390*** (0.059)	0.140*** (0.020)	0.121*** (0.021)	0.129*** (0.017)
Population (million)	0.060*** (0.021)	0.021** (0.008)	0.022** (0.010)	0.017*** (0.005)
Fertility	3.292*** (0.995)	-0.069*** (0.029)	1.185*** (0.290)	0.869** (0.393)
Host ₋₂	-1.761 (1.332)	-0.677 (0.493)	-0.576 (0.564)	-0.508 (0.625)
Host ₋₁	-2.429** (0.918)	-0.875 (0.729)	-0.590 (0.492)	-0.964** (0.423)
Host _{ongoing}	2.964** (1.399)	2.019*** (0.602)	1.036 (0.836)	-0.091 (0.694)
Host ₊₁	-1.882* (0.955)	-0.627 (0.824)	-0.229 (0.472)	-1.026** (0.501)
Host ₊₂	-1.512 (1.227)	-0.591 (0.849)	-0.620 (0.697)	-0.301 (0.711)
Neighbour ₋₂	-1.864** (0.768)	-0.717 (0.502)	-0.801*** (0.211)	-0.346 (0.513)
Neighbour ₋₁	-2.183** (1.020)	-0.702* (0.409)	-0.863* (0.504)	-0.617 (0.543)
Neighbour _{ongoing}	-1.636 (1.046)	0.227 (0.539)	-0.991** (0.460)	-0.872** (0.383)
Neighbour ₊₁	-0.819 (1.071)	0.089 (0.560)	-0.164 (0.428)	-0.744 (0.492)
Neighbour ₊₂	0.807 (1.132)	0.534 (0.566)	0.639 (0.568)	-0.666 (0.585)
Constant	-12.848*** (3.138)	-5.097*** (1.237)	-4.306*** (1.250)	-3.445*** (1.219)
R ²	0.474	0.372	0.308	0.364
F(13, 33)	34.36 ***	29.43 ***	31.27 ***	32.90 ***
Country dummies	yes	yes	yes	yes

Note: Inside parentheses robust standard errors. ***, **, * denote statistical significance at the 99%, 95%, and 90% levels of confidence. The number of observations in all regressions was 267 (n=267).

Discussion and Conclusion

The Winter Olympics are a truly global event with economic, cultural and political effects around the world. Olympic medals are very scarce and sought-after resources on both a national and individual level. Like industrial production, Olympic success requires factor inputs to produce the athletes that place on the podium. This success requires individual-level inputs, such as talent, motivation and training, as well as society-level inputs, such as sports facilities and money. However, a good outcome is not guaranteed, even with large and well-intentioned contributions.

Our data covers the years 1924–2022. The longest time series has been used in the descriptive tables and figures. This study analyses the success of the Winter Olympics and econometric modelling covers the Games organised between 1960 and 2018—the availability of macro data prevented the use of a wider time series. The purpose was twofold. We began by examining whether and how the host effect, in addition to macroeconomic factors, is related to a nation's success in the Winter Olympics, then we analysed how hosting the Winter Olympics affects neighbouring countries.

In line with Bernard and Busse (2004) and Shibli et al. (2012), we have shown that hosting the Winter Olympics is related to medal success. Our estimations indicate that being an Olympic host for the ongoing Winter Games increases the likelihood of winning medals. Additionally, we found some indication (in OLS-regressions), that the host effect shows an inverted U-shaped connection between the host effect and Winter Olympic success. In this way, the standardised beta-value for the host variable is at its lowest position eight years before hosting the Olympic Games, the host effect is strongest during the ongoing Games, and eight years after hosting the Games, the host effect descends back to the lower position. However, in panel analysis after taking account of fixed country effects, the host effect is positive only for ongoing Games.

Furthermore, our exploratory analysis revealed a potential increasing time trend related to the neighbour effect. Although the neighbour coefficients are not consistently statistically significant across specifications, the pattern suggest that any such effect may emerge gradually and could peak several years after the host country stages the Games. This implies that enthusiasm generated by the Olympics might diffuse to neighbouring countries over time, even if the magnitude of this phenomenon remains uncertain.

Given the limited statistical evidence, these findings should be interpreted cautiously. They nevertheless raise an interesting hypothesis of possible spillovers of Olympic enthusiasm may extend beyond national borders and persist for several years. Future research with more detailed data could better identify whether hosting the Winter Olympic Games generates systematic long-term benefits for neighbouring countries.

Hosting the Winter Olympic Games should be seen as a long-term investment. This argument could be used by the International Olympic Committee (IOC) for marketing purposes and to emphasize future opportunities for potential Olympic host countries. In addition, Olympic host countries can justify the vast monetary and infrastructure investments in the Olympic facilities and sports-related expenditures when the tangible benefits of hosting the Games become evident. To the best of our knowledge, inverted U-shaped connection between the host effect and Winter Olympic success has not previously been documented. Nevertheless, a similar effect has been observed in the case of the Summer Olympic Games (Kari, Mangeloja & Tohmo, 2022).

We found that fertility is not negatively correlated with Olympic success. The panel estimation method with country-level fixed effects seems to obliterate the effect of fertility found with less advanced statistical methods. Nevertheless, it may be that this phenomenon is not solely due to statistical properties. There exists an increasing amount of new economic literature noting that the income–fertility relationship is nowadays largely flat or even positive.

In line with earlier studies (e.g. Moosa & Smith, 2004; Johnson & Ali, 2004; Bernard & Busse, 2004; Krishna & Haglund, 2008; Vagenas & Vlachokyriakou, 2012), we found that several macroeconomic factors explain Olympic success. In particular, GDP per capita, population size and health measured as fertility were found to be positively connected to the total medals won in the Winter Olympic Games. In general, our panel regression model explains approximately 47% of the variation in Olympic medal count. This result is lower than the findings of De Bossher et al. (2006), who summarised the previous literature on macro-level factors in explaining international sports success. In conclusion, more than half of the variation in international success could be explained by macro-level variables (De Bossher et al., 2006). According to earlier literature, however, the importance of macro-level factors in explaining Olympic success has seen a decreasing trend in the last decades (Bernard & Busse, 2000; Stamm & Lamprecht, 2000). According to Bernard and Busse (2000), for example, the marginal effects of GDP and population have systematically declined over time; the coefficients for GDP and population were less than half of their 1964 values in 1996 (Bernard & Busse, 2000). Similarly, Stamm and Lamprecht (2000) documented that macro-level factors explained around 60% of international sporting success between 1964 and 1980, while they only explained 45% of success after 1980. Our findings suggest that this declining trend may have continued, since our model that included macroeconomic variables explains less than 50% of Olympic success. Although the explanatory power of the macroeconomic factors has decreased over the years, the impact of these factors in explaining Olympic success remains high.

Although our analysis has mainly focused on macroeconomic and demographic determinants of success, the host and neighbour effects can also be understood as socio-cultural phenomena. Hosting the Games is not only a matter of financial resources or infrastructure but

also creates a unique social environment that influences athletes' performance and the collective memory of the event.

For host athletes, competing in familiar surroundings with strong public support may provide a decisive psychological advantage. For example, at the 2002 Salt Lake City Winter Olympics, U.S. alpine skiers and skaters spoke of how competing “at home” meant reduced travel strain, familiar food, language, and the morale boost of performing before family and friends, elements that collectively contributed to heightened motivation and a sense of comfort. One athlete remarked, “*it’s like your hometown*” when describing competing in the United States (washingtontimes.com).

Neighbouring countries may also be influenced by this heightened atmosphere. When Winter Olympics are hosted in a neighbouring or regionally connected country, the media spotlight could extend beyond national borders, fan enthusiasm might intensify in adjacent regions and athletes may benefit from easier logistical access or cultural proximity. If present, such dynamics could extend the host effect into a broader neighbour effect, potentially reinforcing not only national pride but also a shared regional sporting identity.

Therefore, the host and neighbour effects should be interpreted not only as econometric outcomes but also as reflections of wider socio-cultural processes: the intensification of national pride, the mobilisation of public interest and investment in sport, and the symbolic value attached to Olympic achievement. These processes help explain why hosting the Winter Olympics tends to produce performance gains beyond what population size, GDP, or fertility rates alone might predict.

While our models have succeeded in explaining success in the Winter Olympics fairly well, there are still some limitations that are important to refer to while interpreting our results in general. As suggested by Henry et al. (2020), these limitations are related to issues

concerning, for example, the sample itself, causality issues⁶, the validity of the outcomes⁷ as well as the reliability and the equivalence⁸. For example, at a country level, the study sample that was used may not necessarily have been representative of the total population, and the results may therefore not be generalisable to the total population. It is also possible that although we took into account a wide range of country-level macroeconomic factors, our results may ignore the impact of broader macro-level factors such as political or cultural factors. In addition, although the focus of the present study was on exploring macroeconomic factors to explain Winter Olympic success, the individual-level factors explaining the success should not be neglected. Therefore, to shed more light on explanations for Olympic success, it would be beneficial for future research if macroeconomic factors together with individual-level factors could be included in the analysis.

An interesting avenue for future research would be to explore the existence and impact of potential push factors that may reduce medal counts for non-host and non-neighbour nations. Are there certain structural or contextual factors that systematically disadvantage some countries. For example, the diminished relevance of fertility as a predictor of medal success might differ when examining nations whose medal counts decline in non-hosting or non-neighbouring years. Similarly, countries that have never won medals could still be affected indirectly in overall performance rankings by the redistribution of medals towards host and neighbouring nations. Investigating these push factors could provide a more complete

⁶ Quantitative analysis cannot be solely the ground for policy, and qualitative analysis can offer information for policy purposes on how, why, under what circumstances and for how long policy actions have proven effective.

⁷ Outcomes are due to the changes in the independent variables.

⁸ Concepts and instruments should measure the same issues in different contexts.

understanding of the dynamics of Olympic success and reveal whether gains for some nations are systematically offset by losses for others.

As the Winter Olympic Games continues to be an important global forum for international cooperation, increasing academic analysis in the future will help to better understand Olympic success. Production efficiency could also be maximised in sports so that scarce sports resources are not wasted. According to our results, investments in Winter Olympic Games are well justified, and the Games may have benefits beyond the success of individual sports. According to Houlihan (2005), for example, Olympic Games and sport itself reduce juvenile offending, decrease obesity and increase social inclusion among marginalised groups. Thus, organising Olympic Games may have an economic, social and cultural impact as well as impacts on prestige, health and physical activity (Truno, 1995; Cashman, 2006). In a broader perspective, these factors may have a greater role than medal success itself when countries are considering their willingness to host the Winter Olympic Games.

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Table 1. Definitions of dependent and independent variables used in the empirical analysis.

Table 2. Characteristics of the Winter Olympic Games (1924–2022).

Table 3. Estimation results for Winter Olympic medal regressions.

Table 4. Estimation results for Winter Olympic medal regressions and standardised coefficients.

Table 5. Estimation results for Winter Olympic medal regressions, Tobit model

Table 6. Estimation results for Winter Olympic medal panel regressions.

Figure 1. Nations, events and sports in the Winter Olympic Games (1924–2022).

Figure 2. Athletes (male and female) in the Winter Olympic Games (1924–2022).

Figure 3. All-time medal winners in the Winter Olympic Games (1924–2022).

Figure 4. The share of medals of the most successful countries (1924–2022).

Figure 5. The share of medals of the least successful countries (1924–2022).

Figure 6. Population and total medals won in the Winter Olympic Games (1960–2022).

Figure 7. GDP per capita and total medals won in the Winter Olympic Games (1960–2022).

Figure 8. Standardised coefficients for host variation (zero on x-axis denotes ongoing Winter Olympic Games).

Figure 9. Standardised coefficients for neighbour variation (zero on x-axis denotes ongoing Winter Olympic Games).

Appendices

Appendix 1

Countries included in our data in alphabetical order:

Australia, Austria, Belarus, Belgium, Canada, China, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Italy, Japan, Kazakhstan, Korea Republic, Latvia, Liechtenstein, Luxembourg, Netherlands, New Zealand, North Korea, Norway, Poland, Romania, Russian Federation, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Ukraine, United Kingdom, United States, Uzbekistan.

Appendix 2. Characteristics of the Winter Olympic Games (1924–2022), the share of medals

Year	Host	Norway	Russia	USA	Austria	Germany	Finland
1924	Chamonix	34.69	0.00	8.16	6.12	0.00	22.45
1928	St. Moritz	36.59	0.00	14.63	9.76	0.00	9.76
1932	Lake Placid	23.81	0.00	28.57	4.76	4.76	7.14
1936	Garmisch- Partenkirchen	29.41	0.00	7.84	7.84	11.76	11.76
1948	St. Moritz	14.71	0.00	13.24	11.76	0.00	8.82
1952	Oslo	24.62	0.00	16.92	12.31	7.69	13.85
1956	Cortina d'Ampezzo	5.56	22.22	9.72	15.28	2.78	9.72
1960	Squaw Valley	7.41	25.93	12.35	7.41	9.88	9.88
1964	Innsbruck	14.42	24.04	6.73	11.54	8.65	9.62
1968	Grenoble	13.21	12.26	6.60	10.38	6.60	4.72
1972	Sapporo	11.43	15.24	7.62	4.76	4.76	4.76
1976	Innsbruck	6.31	24.32	9.01	5.41	9.01	6.31
1980	Lake Placid	8.77	19.30	10.53	6.14	4.39	7.89
1984	Sarajevo	7.76	21.55	6.90	0.86	3.45	11.21
1988	Calgary	3.62	21.01	4.35	7.25	5.80	5.07
1992	Albertville	11.70	13.45	6.43	12.28	15.20	4.09
1994	Lillehammer	14.21	12.57	7.10	4.92	13.11	3.28
1998	Nagano	12.20	8.78	6.34	8.29	14.15	5.85
2002	Salt Lake City	10.64	5.53	14.47	7.23	15.32	2.98
2006	Turin	7.54	8.73	9.92	9.13	11.51	3.57
2010	Vancouver	8.88	5.79	14.29	6.18	11.58	1.93
2014	Sochi	8.87	9.90	9.56	5.80	6.48	1.71
2018	Pyeongchang	12.66	5.52	7.79	4.55	10.06	2.27
2022	Beijing	11.31	9.79	7.65	5.50	8.26	2.45
Average		14.18	11.08	10.28	7.73	7.72	7.13

Appendix 3. Characteristics of the Winter Olympic Games (1924–2022), the share of medals

Year	Host	Sweden	Canada	Switzerland	East Germany	France	Netherlands
1924	Chamonix	4.08	2.04	6.12	0.00	6.12	0.00
1928	St. Moritz	12.20	2.44	2.44	0.00	2.44	0.00
1932	Lake Placid	7.14	16.67	2.38	0.00	2.38	0.00
1936	Garmisch- Partenkirchen	13.73	1.96	5.88	0.00	1.96	0.00
1948	St. Moritz	14.71	4.41	14.71	0.00	7.35	0.00
1952	Oslo	6.15	3.08	3.08	0.00	1.54	4.62
1956	Cortina d'Ampezzo	13.89	4.17	8.33	0.00	0.00	0.00
1960	Squaw Valley	8.64	4.94	2.47	0.00	3.70	2.47
1964	Innsbruck	6.73	2.88	0.00	0.00	6.73	1.92
1968	Grenoble	7.55	2.83	5.66	4.72	8.49	8.49
1972	Sapporo	3.81	0.95	9.52	13.33	2.86	8.57
1976	Innsbruck	1.80	2.70	4.50	17.12	0.90	5.41
1980	Lake Placid	3.51	1.75	4.39	20.18	0.88	3.51
1984	Sarajevo	6.90	3.45	4.31	20.69	2.59	0.00
1988	Calgary	4.35	3.62	10.87	18.12	1.45	5.07
1992	Albertville	2.34	4.09	1.75	0.00	5.26	2.34
1994	Lillehammer	1.64	7.10	4.92	0.00	2.73	2.19
1998	Nagano	1.46	7.32	3.41	0.00	3.90	5.37
2002	Salt Lake City	3.40	7.23	4.68	0.00	4.68	3.40
2006	Turin	5.56	9.52	5.56	0.00	3.57	3.57
2010	Vancouver	4.25	10.42	3.47	0.00	4.25	3.09
2014	Sochi	5.12	8.53	3.75	0.00	5.12	8.19
2018	Pyeongchang	4.55	9.74	4.87	0.00	4.87	6.49
2022	Beijing	5.50	7.95	4.28	0.00	4.28	5.20
Average		6.21	5.41	5.06	3.92	3.67	3.33

Appendix 4. Characteristics of the Winter Olympic Games (1924–2022), the share of medals

Year	Host	Japan	South Korea	China
1924	Chamonix	0.00	0.00	0.00
1928	St. Moritz	0.00	0.00	0.00
1932	Lake Placid	0.00	0.00	0.00
1936	Garmisch- Partenkirchen	0.00	0.00	0.00
1948	St. Moritz	0.00	0.00	0.00
1952	Oslo	0.00	0.00	0.00
1956	Cortina d'Ampezzo	1.39	0.00	0.00
1960	Squaw Valley	0.00	0.00	0.00
1964	Innsbruck	0.00	0.00	0.00
1968	Grenoble	0.00	0.00	0.00
1972	Sapporo	2.86	0.00	0.00
1976	Innsbruck	0.00	0.00	0.00
1980	Lake Placid	0.88	0.00	0.00
1984	Sarajevo	0.86	0.00	0.00
1988	Calgary	0.72	0.00	0.00
1992	Albertville	4.09	2.34	1.75
1994	Lillehammer	2.73	3.28	1.64
1998	Nagano	4.88	2.93	3.90
2002	Salt Lake City	0.85	1.70	3.40
2006	Turin	0.40	4.37	4.37
2010	Vancouver	1.93	5.41	4.25
2014	Sochi	2.73	2.73	3.07
2018	Pyeongchang	4.22	5.52	2.92
2022	Beijing	5.50	2.75	4.59
Average		1.42	1.29	1.25