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An Old Boys' Club No More: Pluralism in Participation and Performance at the Olympic Games

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Abstract

This paper examines the growing diversity of participation and achievement in the Olympics. A wide set of socioeconomic variables is correlated with medaling, particularly with respect to the Summer Games and women's events. Host advantage is particularly acute in judged contests such as gymnastics. However, there is evidence that the influence of correlates such as country size, per capita income, and membership in the communist bloc is declining over time as competition becomes increasingly diverse. These effects are less evident in the Winter Games, events that require significant capital investments, and judged contests.

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The Olympic Games are arguably the most global organized sporting event on earth. At the 2012 Summer Games, 10,500 athletic participants—4,700 of which women—from over 200 nations went head to head in sporting disciplines from aquatics to wrestling and fencing to judo. Hosting the Games has been a coveted honor and can act as a powerful signal that an emerging power has arrived on the world stage. This symbolism was most recently evidenced in China in 2008, when 25,000 accredited media personnel from 159 countries, joining hundreds of thousands of foreign visitors, descended on Beijing to beam back the unfolding drama to billions of viewers at home.

But the Olympics have not always been this way. The origins of the modern Games strongly reflected the vision of the movement's founder, French nobleman Pierre de Courbetin. His was a 19th century liberal conception of competition among individual amateur athletes, in effect gentlemen (Guttmann 2002). Given this aristocratic perspective, it is perhaps not surprising that at the first modern Games in 1896, athletes from the 14 participating nations who took home medals were all European, American, or Australian. Women did not compete in those initial Games, and after competition was fitfully opened to them beginning in 1900, participation remained limited. Even immediately after World War II, the Summer Games and, especially, the Winter Games were still predominantly a showcase for European male athletic talent: At the London Summer Olympics and the St. Moritz Winter Olympics in 1948 men from Europe and the United States constituted 62 and 82 percent of total athletic participants, respectively.[1]

Geographic diversity of representation at the Summer Olympics has steadily increased in the postwar period, save 1976 and 1980, which were marred by large-scale boycotts (figure 1). By London 2012, African and Asian countries constituted almost half of the represented National Olympic Committees (NOCs) and a quarter of the participating athletes. Multi-regional gains have been far less comprehensive in the Winter Games but are on an upward trend (figure 2). In the first postwar Games, 83 percent of all athletes were from Europe; 66 years later, this figure has dropped to only 68 percent. In addition to geographic diversity, gains in female representation have been comprehensive in both seasons: Women now make up almost half of the athletes at the Summer and Winter Olympic Games (figure 3). Finally, we should not forget that these headline numbers overlook the increasingly rich ethnic, cultural, and societal diversity in each individual national delegation.[2]

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1. This paper groups countries according to the International Olympic Committee's continental associations, of which there are five: Africa, Americas, Asia, Europe, and Oceania.

2. Three recent examples come to mind. At London 2012, Saudi Arabia lifted a ban on female competitors, allowing women to represent the country for the first time, along with Qatar and Brunei Darussalam; these were the last Summer Olympics participants to have male-only delegations (IOC 2012). In another example from the 2012 Games, 60 of the 542 athletes fielded by Great Britain's Olympics delegation were born in well over a dozen foreign countries, a reflection of the ethnic and cultural diversity of the United Kingdom (Hart 2012). Finally, at the 2006 Olympic Games, participation by nonwhite athletes on Team USA was noted to have nearly quadrupled from eight years prior at Nagano (VOA 2009).

Diversity has increased not only in representation but also in who takes home medals. Figure 4 shows the share of medals won by the top 10 contenders at each Olympics.[3] From the height of the boycotted 1980 Moscow Games, in which East Germany and the USSR took home 51 percent of all available medals, medal-winning concentrations in both Games became incrementally more dispersed among NOCs until leveling out in the late 1990s. Not surprisingly, this also coincides with a period in which many more countries were entering competition, as well as the breakup of the Soviet Union and entry of individual post-Soviet state competitors. But a simple increase in the number of potential participating countries is not the whole story: As we demonstrate, both shifts in the cross-country distributions of the underlying correlates and changes in the parameter values of those correlates over time have contributed to this growing pluralism of outcomes.

This paper models the historical determinants of success at the Olympic Games in the context of these events' growing pluralism, evolving from their aristocratic and largely European male roots to the more gender-inclusive and geographically diverse showcase of athletic talent that we see today. There is a growing body of empirical research on the Olympics: Some of this work (Bernard and Busse 2004, Johnson and Ali 2004, Lui and Suen 2008, Celik and Gius 2014) has tested the determinants of total NOC medal outcomes at the Summer Games, while related efforts have focused on the performance of particular regions (Hoffmann, Lee, and Ramasamy 2004).[4] Other researchers (Klein 2004, Leeds and Leeds 2012, Lowen, Deaner, and Schmitt 2014, Noland and Stahler 2015) studied female athletic inclusion and success specifically. A third group of researchers has statistically modeled outcomes for the Winter Games (Pfau 2006) and for individual sports (Balmer, Nevill, and Williams 2001, 2003, Tcha and Pershin 2003, Otamendi and Doncel 2014).

We model the determinants of country-specific medal shares at both the Summer (1960–2012) and Winter (1960–2010) Games. Not only is our sampling frame extended, allowing us to model how specific determinants of success have increased or decreased in importance over time, as the Games became more globally inclusive, but we also pay close attention to the growing importance of women's athleticism at these events, and how determinants of success of female athletes differ from those of their male counterparts. Finally, thanks to the contributions of the International Olympic Committee's (IOC) Research Center, we also test determinants of success down to the granular level of both sports-specific

3. An arguably more sophisticated way to measure the dispersion of winnings among competitors is to compute modified Herfindahl indexes as developed by Otamendi and Doncel (2014) for each year and observe changes over time. Not surprisingly, Herfindahl indexes demonstrate very similar trends in medal concentration among each season over this period.

4. Celik and Gius (2014) also test for the determinants of medal winnings per athlete, which can be thought of as a proxy for a country's medal-winning efficiency. While this is an interesting avenue of research, we do not include these estimations for the sake of brevity.

and gender-specific outcomes at the Olympics. In this last instance, our study provides the most robust research that we are aware of.

In line with other studies, we find that determinants such as income, country size, status as a current host, and inclusion in the communist bloc have generally been historically significant for both female and male success. But a clear narrative thread is also couched in the pluralization of Olympic competition throughout the postwar period. At the Winter Games, which are not drastically different from the 1960s in terms of their geographical makeup, success is still largely associated with being from a rich, large country with a snowy climate. In contrast, the Summer Games, where geographic pluralization has been much more comprehensive, exhibit more subtle determinants of success reflective of their diversity. Rather than per capita income, education is a much more robust positive determinant of medal winnings, and this appears to have been far more important for women than men. Moreover, we uncover evidence that the estimated coefficients for the Summer Games have changed over time—specifically even these robust correlates are waning in their influence and as this occurs, smaller, poorer, even possibly less educated countries face fewer barriers to achieving Olympic glory.

An examination of event-specific data supports this basic narrative. The correlation between per capita income levels and outcomes is not evident in sports such as athletics and boxing, which generally require little equipment, while the necessity of large capital expenditures on infrastructure and equipment for sports such as aquatics and cycling appears to continue to constitute a barrier to entry in some events. Having the "home-field" may be more advantageous for judged sports such as gymnastics, as is the case for being from the communist bloc. East Germany, during the height of its doping years, unduly benefited within nonjudged events such as aquatics and athletics, where strength and stamina mattered comparatively more. The impact of the East German doping program is much more evident in women's events, where the doping effort was concentrated.

Looking forward, these results suggest that in events such as athletics, a widening group of countries is likely to achieve success, but this pluralization of outcomes will come more slowly in the Winter Games, events that require significant capital investment, and in judged contests.

MODELING DETERMINANTS OF SUCCESS AT THE SUMMER AND WINTER GAMES

While there is clearly evidence of increased diversity and pluralism in participation, the story is less clear with respect to medal outcomes. Table 1 reports country rankings by total, male, and female medal shares averaged over all Olympic performances at the Summer Games (1960–2012) and Winter Games (1960–2010). In both seasons, the Soviet Union appears to have been the overall champion, where on average the nation claimed 20 percent of the medals available at a given Olympic performance. The United States and Germany in its various forms (East, West, the Unified team, and modern Germany) have also been exceptional performers in both Games. There is a pronounced "clumping" among elite athletic countries: At the Summer Games, 32 percent of all medals awarded throughout this period have gone to the United States, USSR, or Germany in its various forms, while 38 percent of NOCs that participated in the 2012 Games have yet to win a single medal.

Table 1 illustrates three particularly germane points. First is the clear regional bias of overall success: Besides Japan and China, every entry on the list is a European country, the United States, Australia, or Canada. In contrast Cuba (20th place) and Brazil (31st place) have been the most successful countries on average in the Caribbean and South America; Kenya (30th place) has had the best average performance of African countries. But these apparent regional disparities may simply be a proxy for income or development level. If that is the case, one might expect to see a growing diversity of medal winners, insofar as global income inequality started declining significantly around the turn of the 21st century and is likely to continue to do so for another two decades or so (Hellebrandt and Mauro 2015).

Second, while a number of similar countries appear in the top rankings for both the Winter and Summer Games, the lists are not exactly the same. For example, Northern European and Nordic countries like Austria, Finland, Norway, Switzerland, Sweden, and the Netherlands are top performers in Winter sports but do not make it to the top 15 in the Summer Games. Finally, levels of success are not necessarily the same between a country's male and female athletic delegation. The Soviet Union and the United States brought home a larger share of female medals on average in both Games, while Italy, Norway, and Sweden have had comparatively more success with their male athletes.[5]

The top-line statistics motivate us to dig deeper into what characteristics of a country could motivate a successful performance at the Olympics, and how this may differ across the Winter and Summer Games, as well as across male and female performances. Our study utilizes an original panel dataset consisting of all 2,056 NOC performances at the Summer Games between 1960 and 2012, and all 760 performances at the Winter Games between 1960 and 2010. Specific data on male and female aggregate and sports-specific medal counts and participation have been generously provided by the IOC Research Center. Control variables for population, adolescent fertility rate, percent population urbanized (1960–2012), and the labor force participation ratio (1996–2012) have been taken from the World Bank. Data on educational levels (1960–2010) have been taken primarily from Barro and Lee (2013). Per capita GDP in constant purchasing power parity (PPP) from 1960–2010 is from the Maddison project.[6] Unless

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5. Nowhere is the difference between average male and female performance more profound than in East Germany, which on average took only 10 percent of male medals throughout their five performances at the Summer Games and an astounding 25 percent of the female-event medals. However, these differentials have been ascribed to a systematic doping policy that specifically targeted East German female athletes (Noland and Stahler 2015).

6. For a detailed accounting of the general data building process, including data sources, assumptions made to include historical Soviet Union-era countries, data limitations, and statistical modeling issues, see the data appendix in Noland and Stahler (2015).

otherwise specified, the dependent variable under scrutiny consists of an individual NOC's share of medals won out of all medals available that Olympic year in male-/female-specific events ("male/female medal share").[7]

Table 2 provides pairwise correlation coefficients showing total medal shares against a vector of relevant control variables. Clearly, status as a current host, being a "communist bloc" country, population size, GDP per capita, and levels of schooling are strongly positively correlated with success, though all effects besides GDP per capita appear to be more powerful for the Summer Games sample. Moreover, while correlation coefficients for male- and female-specific medals don't display huge differences, it looks as if, among other things, per capita income may matter more for male medals than female medals. In fact, many of these variables do not seem to be particularly good explanators of female success in the Winter Games.

Correlation coefficients say nothing of causality and motivate the application of formal statistical models. Previous research, notably Bernard and Busse (2004), has focused on country size and income level as the main predictors of Olympic success. Specifically, Bernard and Busse posit a model in which countries produce Olympic caliber athletes using people, money, and some organizational capacity using Cobb-Douglas technology,

1) $$T_{it} = f(N_{it}, Y_{it}, A_{it}),$$

where T is talent, N is population, Y is national income, A is organizational capacity, and the subscripts i and t refer to country and year, respectively. $\Sigma_j medals_{jt}$ represents the summation of all medals won by all countries at a given Games. A country's share of Olympic medals is a function of talent, and a log function translation of talent into medal shares:

2) $$E\left(\frac{medals_{it}}{\sum_j medals_{jt}}\right) = M^*_{it} = \mathrm{g}(T_{it}).$$

The following yields a specification for medal shares:

In general, we acknowledge here that our data panel is necessarily unbalanced by the very nature of the Olympics movement, as more countries join the Games throughout the sampling period and historical countries like East Germany and the USSR cease to exist. It should also be noted that there are significant problems related to estimating the GDP of historic communist countries, where much of the data are unreliable and difficult to compare with market economies and could lead to biased coefficients. This work almost exclusively uses GDP per capita estimations from the work of Angus Maddison.

7. In addition to female- and male-specific events, the Olympic Games also field mixed-gender events. In this study, "mixed" event outcomes are treated as extraneous and not included in estimations of male- or female-specific events.

$$3) \quad M_{it} = \begin{cases} \ln A_{it} + \gamma \ln N_{it} + \theta \ln Y_{it} - \ln \sum_j T_{jt} & \text{if } M_{it}^* \geq 0, \\ 0 & \text{if } M_{it}^* < 0. \end{cases}$$

Because national income can be expressed as the product of population and per capita income, the previous condition can be restated as

$$4) \quad M_{it} = \begin{cases} C + \alpha \ln N_{it} + \beta \ln (Y/N)_{it} + d_i + v_i + \epsilon_{it} & if\ M_{it}^* \geq 0, \\ 0 & if\ M_{it}^* < 0, \end{cases}$$

yielding a model that can be estimated:

$$5) \quad M_{it} = C + \alpha \ln N_{it} + \beta \ln \left(\frac{Y}{N}\right)_{it} + Host_{it} + Soviet_{it} + Planned_{it} + d_i + v_i + \epsilon_{it},$$

where the NOC share of total medals won is a function of log population and GDP per capita, together with dummy controls for Olympic host countries and whether it was a Soviet or planned economy.

However, we have strong reason to suspect that there are other significant socioeconomic and geographic determinants of medaling in the error term ϵ_{it} that are collinear with the independent controls: For example, measures of income are also tightly correlated with educational attainment. From the selection of possible control variables shown in table 2, we strip out regressors that offered little explanatory power and specify our core model of Olympic success at the Summer Games: [8]

$$6) \quad M_{it} = C + \beta_1 \ln N_{it} + \beta_2 \ln \left(\frac{Y}{N}\right)_{it} + \beta_3\, Edu_{it} + \beta_4 Eqdist_{it} + Host_{it} + PostHost_{it} + CommBloc_{it} + Boycott_t + EG_i + Dope_{it} + \sum_{t=1960}^{2012} \delta_t + \epsilon_{it}\ \text{z}$$

where our dependent variable(s) indicate an individual NOC's share of total medals won out of all medals available in male- or female-specific events. Our independent controls include log GDP per capita at PPP prices $\ln\left(\frac{Y}{N}\right)_{it}$, logged population N_{it}, average years of total schooling among the 15+ year-old population Edu_{it}, and geographical distance in degrees of latitude from the equator $Eqdist_{it}$. Additionally, we include dummy variables to control for whether an NOC was the host of the Olympic Games $Host_{it}$ or if it hosted the previous Games $PostHost_{it}$, whether it is currently a member of the communist bloc $CommBloc_{it}$, and

8. Adolescent fertility rates and percent population urbanized were largely insignificant or evidenced extremely minor marginal effects in regressions. Dummies such as "small state" and landlocked were also frequently insignificant, or when significant appeared to be statistical artifacts, driven in the Winter Games, for example, by Switzerland and Austria being landlocked countries.

whether the NOC participated in one of the major boycott years of 1980 and 1984 $Boycott_t$. Finally, motivated by the finding of an extremely powerful "doping" effect for East Germany at the height of its Olympic prowess (Noland and Stahler 2015), we add a control for East Germany between 1976 and 1988, which proxies for a "doping" dummy $Dope_{it}$, as well as the East German fixed effect EG_i.[9]

The core specification of the Winter Games is exactly the same, save that the sample is from 1960–2010, and we add in one more time-invariant dummy to indicate countries that get heavy frost in the winter ($Frost_i$):[10]

$$M_{it} = C + \gamma_1 \ln N_{it} + \gamma_2 \ln\left(\frac{Y}{N}\right)_{it} + \gamma_3\, Edu_{it} + \gamma_4 Eqdist_{it} + Frost_i + PostHost_{it} + Host_{it} + CommBloc_{it} + Boycott_t + EG_i + Dope_{it} + \sum_{t=1960}^{2010} \delta_t + \in_{it} \quad (7)$$

In tables 3 and 4, we estimate the core model in three separate ways: First, we show a tobit model censored at the zero lower bound due to the high incidence of NOCs that do not report winning any medals (3.1, 3.4, 4.1, 4.4)[11]; second, we add a t–1 lagged dependent variable to account for an NOC delegation's apparent legacy effect (3.2, 3.5, 4.2, 4.5); third, we estimate a random effects tobit, which takes into account country-specific effects (3.3, 3.6, 4.3, 4.6). For robustness purposes, we also estimate uncensored standard ordinary least squares (OLS), OLS with a lagged dependent variable, and fixed effects models; results can be found in appendix tables A.1 and A.2. As shown in table 3, tobit results are generally consistent for the Summer Games in terms of sign and significance. Logged population is always positive and significant, as are average years of total schooling, current host, and the communist bloc dummy. Log GDP per capita is positive and significant in four of the six estimations. (GDP per capita is

9. East Germany engaged in a systematic and invasive program of administering performance enhancing drugs (PEDs) to 10,000 athletes, particularly female competitors (Franke and Berendonk 1997, Yesalis, Kopstein, and Bahrke 2001, Hunt 2011, Ungerleider 2013). This program was applied comprehensively between 1976 and1988, at a time when the country brought home astounding shares of female medals, including 33 and 39 percent of medals awarded at the 1976 and 1980 Summer Games, respectively. Noland and Stahler (2015) estimated that during this period East German doping accounted for 17 percent of the medals awarded to women, equivalent to the medal hauls of the Soviet or American team in 1972, the last Olympics not marred by widespread abuse of PEDs. For this purpose, we estimate "doping" by giving East Germany observations a dummy that switches on in 1976, 1980, and 1988. We also separately control for the East German fixed effect, but this coefficient is not reported.

10. Distance from the equator is measured in the degrees of latitude from the central point in a country, divided by 100. The vast majority of these values are taken from Laitin, Moortgat, and Robinson (2012), with a handful of missing values substituted from internet searches. Regarding the "frost" dummy, NOCs receive a 1 if more than half a country's land mass receives heavy frost for 20 or more days per month in the winter. The data are from Masters and McMillan (2001).

11. In the Winter Games (1960–2010), 44 percent of observations report zero female medals won, and 67 percent report zero male medals won. In the Summer Games (1960–2012), 56 percent of observations report zero female medals, and 62 percent report zero male medals. This would imply significant clumping at the zero lower bound in both samples, motivating the use of tobit models.

actually highly collinear with distance from the equator. If distance from the equator is dropped from the specification, the coefficient on per capita income is always significant.)

There is also notable variation between male- and female-specific outcomes. Wald tests show that female medal shares are significantly more positively affected by population size than male medal shares, as is the case with total schooling and being part of the communist bloc.[12] Interestingly, Wald tests also suggest that the legacy effect is slightly—but significantly—less powerful for women compared with men. Indeed, this result may be both a cause and effect of some national sports programs specifically targeting women's competitions on the belief that the marginal impact of interventions is higher than in men's events due to shallower depth of competition and/or weaker legacy effects (Dong 2011, Hunt 2011).

The Winter Games paint a different story of determinants of success and possibly, due to the much more restricted sample of competitors, is simply more idiosyncratic.[13] Neither being a host nor a member of the communist bloc is as powerful as that evidenced in the Summer Games, and for women these determinants are largely insignificant. Not surprisingly, geographical determinants suggesting a colder climate, such as distance from the equator and whether one's country receives heavy frost in the winter, are substantively more important for success. Average total years of schooling do not appear to be significantly associated with medaling at all. In a statistically significant sense, the coefficients on GDP per capita, population, the frost dummy, and the "doping" dummy differ between genders.

But the major standout is per capita income, which is not only highly significant but also orders of magnitude higher than the Summer Games in substantive effect. These results are, in fact, unbelievably high when applied to substantive effects in the uncensored range (i.e., a 1 percent increase in GDP per capita leads to between 4 to 9 percent gain in *all* medals available in gender-specific events) and most likely a byproduct of censoring. Appendix table A.2 shows the same models estimated using uncensored OLS and fixed effects models. Here, returns to per capita income are within the range of a 0.4 to 2.4 percent medal share gain, on average, for every 1 percent gain in GDP per capita. While much lower than

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12. To test whether the determinants of male and female medaling are significantly different from each other, we run separate estimations of male medal shares and female medal shares on the same vector of controls using the standard tobit model (see specifications 3.1 and 3.4). We then combine estimation results using Stata's "suest" command, accounting for robust errors clustered by NOC. Finally, we run Wald/Chow tests for equality of coefficients and designate results as significantly different if they are below the 0.1 p-value cutoff. For robustness purposes, we conducted the same operation using tobit models with lagged dependent variables (specifications 3.2 and 3.5) to find similar results.

13. From a theoretical standpoint, modeling the Winter Games may be trickier than modeling the Summer Games due to sampling bias produced by the less inclusive nature of the sporting events, which generally require a snowy climate to train, and participating countries. As a potentially viable alternative approach to correct this bias, one could employ a multi-stage Heckman-style approach wherein NOCs are first "selected" into the estimation based on their propensity to medal. The authors, however, could not identify a strong selection variable that is required for Heckman models, but this is an interesting avenue for future research.

the tobit variant, these are still significantly higher returns than those found in either the Summer tobit (table 3) or uncensored (appendix table A.1) regressions.

One last result of note is the performance of the East German doping dummy. In the tobit and random effects tobit models for both the Summer and Winter Games, we find a huge boost to female performance (18 percent in Summer Games and 22 percent in Winter Games), with a lesser but still notable boost to male performance as well (5 percent in Summer Games and 7 percent in Winter Games). These results also hold in uncensored estimations. This lends credence to the initial findings reported in Noland and Stahler (2015), showing that the "doping" effect may have been not only enormous for East Germany but also more important for female performance where the performance-enhancing drugs (PED) program was concentrated. However, when combined with a lagged dependent variable, the doping effect frequently disappears. This should not necessarily be read as a confounding result: Once the influence of doping is established it effectively becomes the "new normal" for East Germany, in essence a fixed effect, and it is not surprising that a lagged dependent variable incorporates the impact of doping.

The previous models produce aggregate determinants of success over our entire sampling period, but how have these determinants changed over time as the Games grew more diversified in terms of geographical and gender representation? To test this, we use the core tobit models estimated above and add in a time-interaction effect for each of our major variables.[14] The coefficient results on the interaction effect are shown in table 5.

For two explanators there is relatively robust evidence of changing impact over time. In five of six Summer Games specifications, the coefficient on population has a negative time trend—being big does not matter as much as it once did, leaving small states at marginally less of a disadvantage in more modern Games. This effect is not observed in the Winter Games, which typically exhibit less systematic results.

The second relatively robust finding is the waning effect of the "communist bloc" dummy over time for both men and women in the Summer Games. There are two nonmutually exclusive explanations. The first is that the communist model of state-sponsored elite athletics became less effective over time, either because of the relative deterioration of the communist countries economically or perhaps due to the increasing professionalism of Western competitors, which leveled the playing field. The other explanation is compositional: European communist countries were particularly successful and with the collapse of European communism, the remaining communist countries, Cuba, Laos, China, and Vietnam, were relatively less effective, though Cuba and China have clearly had their successes.[15] The relatively more

14. Specifically, we interact each of our major control variables with a "time period" variable that ranges from 1 (i.e., the 1960 Games) to 14 (i.e., the 2012 or 2010 Games, depending on season). Here we think of diversification in gender and geographic representation as a function of a linear time trend, which is not an unreasonable assumption.

15. North Korea is another post-Soviet breakup communist state that has a consistent presence at the Summer Games. However, this country is not included in regressions due to lack of adequate control data.

rapid deterioration of the "communist edge" for women could be consistent with either explanation—the level of gender equality in communist societies relative to noncommunist countries declined as women's status rose in the West, or European communist countries had higher levels of gender equality relative to their Asian brethren, so when European communism disappeared, the communist edge declined. Further robustness tests support the latter explanation. Estimating the same regression for the 1960–1988 and 1992–2012 samples separately, the significance of a waning communist interaction effect completely disappears in both. The fall of the Soviet Union was clearly a significant break for the power of communist states to affect medal outcomes.

The rise of professionalism is another development that could contribute to changes in correlates over time. Many of the founders of the modern Olympic movement subscribed to notions of amateurism, but the clear if uneven trend has been toward greater acceptance of financial reward for athletes, whether in the form of direct payments or indirectly through product endorsements. The acceptance of professionalism gained momentum with the emergence of participation by Soviet and other Eastern bloc NOCs, which operated systems that made their competitors professionals in all but name only. Tolerance of professionalism varied across sports federations, but by consensus the 1992 Barcelona Games were the first "professional" Games, particularly notable for the participation of the US "Dream Team" of professional men's basketball players from the National Basketball Association.

One possibility is that if professionalism is tolerated openly, the impact of per capita income may be reduced since athletes from poor countries (who might face the biggest incentives to give up their amateur status) could openly turn professional. The other possibility is that sports require all sorts of training facilities, specialized coaching, and medical care, and if professionalism is permitted openly, then professionals from high-income countries are more likely to be able to access these performance-supporting inputs due to their far larger and more lucrative venues for professional competition. From this perspective, the regressions reported in table 5 do not robustly support either hypothesis, nor are significant results obtained when the sample is split at 1992.

Overall, time-interaction effects appear to indicate that many of our control variables mattered marginally less—not more—as the Summer Games became progressively more pluralist. Not being a communist or coming from a smaller country became less of a handicap for nations—and in the case of communism the advantage completely disappeared. Moreover, there is less robust evidence that women from poorer and less educated countries also faced marginally less of a barrier to success as pluralism flourished in the Summer Games. These changes in parameter values, together with increases in the degree of cross-country income and educational attainment equality could contribute to the observed diffusion in medal winning. The Winter Games, which have not made nearly the same advances in the diversity of their representation, tellingly exhibit mostly null results with respect to changes in the estimated coefficients that could contribute to an effective lowering of entry barriers.

EVENT-SPECIFIC DETERMINANTS

The analysis thus far has addressed participation and performance at the aggregate level. But the Olympics involve an enormous range of competitions, and examination of event-specific outcomes may yield additional insights.

Breaking out concentrations of medal winnings by a few major sporting categories demonstrates a trend towards increased dispersion of winnings, with some of the biggest drops in sports like athletics and skating taking place after the dissolution of the Soviet Union (figure 5). Nonetheless, there has been a great deal of sports-specific variance in terms of winnings concentrations. Table 6 lists all sporting categories of the Summer Games, ranked from least concentrated to most concentrated in terms of historic winning shares.[16] The results are eye-opening. Athletics, the sporting category with historically the most events and medals available for contestation, is in 6th place, while medal wins in aquatics, which has awarded the second most medals, are actually highly concentrated among some elite competitors (in this case, the United States).[17] Instead, winnings in shooting, sailing, and martial arts such as taekwondo have been the most dispersed among NOCs. The most widely dispersed winnings of any male sport in the modern period has been boxing, and while competition in the sport opened to women only in 2012—making gender outcome comparisons unadvisable—female boxing medals may also grow increasingly dispersed with subsequent games. On the reverse end of the spectrum, winnings in badminton and especially table tennis have completely been locked down by a few countries, notably China. Table 7 ranks all seven Winter sports by their medal-winning concentrations. Here, the larger sporting categories of skiing and skating are also the most diversified in terms of winnings. Ice hockey and curling bottom out the list, with Canada dominating both.

There are also differences in the patterns of medal-winning concentrations across gender. On average, female winnings are slightly more concentrated than male winnings, though this could be due to the fact that women have had less opportunity to compete in many of these events. However, if we compare cases where the number of available medals has been the same, or almost the same, for women and men (i.e., handball, tennis, gymnastics, archery, triathlon, badminton, table tennis) the tendency toward

16. Sports are ranked from least concentrated to most concentrated according to modified Herfindahl indexes as described in Otamendi and Doncel (2014). Index results closer to zero imply that medal winnings for a given sport are more dispersed among competitors. Conversely, a Herfindahl score of 1, or close to 1, means that a single country, or a small group of countries, completely dominates medal winnings. Specifically, we rank this chart according to the arithmetic average of derived Herfindahl indexes in male and female events.

17. The authors originally surmised that concentration indexes would be highly correlated with the total number of medals available. While this appears to hold for some sporting categories where only three medals are available per year (hockey, basketball, etc.), it is not necessarily the case in general. Correlation coefficients are –0.39 for men and –0.30 for women.

greater country concentration of medal winning in female competitions still holds, and frequently with significant differences (tennis, badminton, table tennis, triathlon, archery).

These results should also serve as a cautionary tale before we begin to estimate sports-specific determinants of success. Winnings in certain sports are highly concentrated among a handful of dominant countries, and in many cases (basketball, football, etc.) there are only three medals available per year, implying that statistical variation may be highly skewed by the idiosyncrasies of the few standouts. Additionally, women had not competed in many sporting events until very recently (boxing is a good example), which would make the comparison of coefficients between male and female outcomes problematic. Therefore, we have decided to conduct estimations only in sports where men and women have both competed for a significant number of medals. The cutoff for estimation is only for sports where there are 12 or more medals (i.e., 4 or more events) contested per Games for both men and women. In the Summer Games, only aquatics, athletics, and gymnastics were sufficiently large to estimate regressions for the full 1960–2012 period. However, we also estimate regressions for aquatics, athletics, canoeing/kayaking, cycling, fencing, gymnastics, judo, rowing, shooting, taekwondo, and weightlifting for the period 1996–2012 in which these sports offered comparable numbers of medals to both men and women.[18]

We opt to estimate results for 11 sports at the Summer Olympics using negative binomial models with year dummies (table 8). As nonnegative count dependent variables are used in negative binomial models, we have also switched from medal shares to the count of total medals won. A few patterns stand out. First, population matters regardless of the sport; a country's size is the most consistent predictor of Olympic performance. That said, the magnitudes of the coefficients vary significantly by sport. Focusing on the upper panel, which reports regressions over the full sample period 1960–2012, being the host country confers a slightly greater advantage in gymnastics—a judged sport—than it does in aquatics or athletics, where performance is typically objectively measured (diving is an exception). The same narrative plays out in the modern sample, where a strong host effect is evidenced in gymnastics, but not in nonjudged sports like cycling, canoeing, shooting, weightlifting, or men's athletics.[19] As such, our findings corroborate those in Balmer, Nevill, and Williams (2003), which found a significant home country advantage in subjectively judged sports like gymnastics but not in objectively judged events (track and field, weightlifting).[20] Qualifications for judges as well as the establishment of judging systems

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18. One bonus of being restricted to the 1996–2012 sample is that we can also control for the gender labor force participation ratio, which was found to be a positive contributor to both female participation and medaling shares in Noland and Stahler (2015).

19. Interestingly, we see a rather large host effect on women's athletics in both the full and modern samples.

20. While not reported in table 8, the host effect of men's weightlifting estimated throughout the 1960–2012 period is an approximately 6 percent bump in medal share, very similar to the coefficients on men's aquatics and athletics, but far below the host coefficient for gymnastics.

are determined on a sport-by-sport basis by the relevant international governing federation. There is no reason to believe that these international governing bodies and their representatives are uniformly competent and incorruptible or respond with equal alacrity and rigor when problems are revealed.[21]

Similarly, being from a communist country confers a bigger advantage in female gymnastics than in aquatics and athletics in the full period. This result could be due to the effectiveness of the communist sports model, but it may also reflect the often alleged political bias of judges in these events. Conversely, doping appears to be relatively effective in women's aquatics and athletics, but not in gymnastics. Similarly boycotts appear to have relatively strong effects in the more objectively judged aquatics and athletics and less of an impact in the more subjectively judged gymnastics. Finally, the coefficient on per capita income is actually negative for gymnastics, particularly women's gymnastics, given the historical dominance of relatively poor countries like East Germany and the Soviet Union, and poor postcommunist bloc states like Romania, Bulgaria, and Ukraine, which continued their success after the fall of the Soviet Union.

The results are generally less robust for the shorter, "modern" sample of 1996–2012. Again, population is a robust predictor of success, but the coefficient magnitudes vary considerably across sports: Population appears to matter a lot in aquatics, fencing, and gymnastics, and relatively little in such events as rowing and athletics. Likewise, the coefficient on per capita income varies considerably across events, ranging from strongly positive (cycling, men's aquatics, and rowing) to insignificant (athletics) to negative (gymnastics). As is the case with the aggregate model, women appear to receive the lion's share of the gains from higher levels of education, posting significant bumps in performance in aquatics, athletics, gymnastics, rowing, and shooting. Most of these educational returns are also significantly different than the returns to their male compatriots. Having a more gender-balanced labor force ratio generally yields more of a marginal return to women's medal winnings, especially in aquatics, gymnastics, and rowing.

In short, smaller, poorer countries fare relatively well in athletics, which are dominated by individual competitions (as distinct from team competitions), and events such as running, jumping, and throwing require little expensive equipment. Competitions that require greater investments in facilities, aquatics, for example, largely remain the domain of larger, richer countries. One possible mechanism that would drive such a result is the IOC policy on participation, where each country has limits on the number of athletes it can enter for any particular event. With the Olympics at the current cap of athletes (at approximately 10,500), these effects bind with the resulting decrease in the magnitude of the coefficients, either because in a probabilistic sense the relative share of "qualified" athletes entered by poor countries (and hence their

21. The most famous corruption case involved the purported influencing of a judge during the pairs' figure skating competition at the 2002 Salt Lake City Games. The fiasco led to the eventual awarding of two sets of gold medals and a revision in the method used to score figure skating. Multiple allegations of interference with judges were also made during the 1988 Seoul boxing competition. In the latter case, these incidents involved competitors from the host country, in the former case it did not.

odds on medaling) is increasing and/or that facing their own budget constraints, NOCs, particularly poor country NOCs, are making strategic choices about which events in which to enter competitors.[22]

In table 9, we show negative binomial models of sports-specific determinants of success for skating and skiing in the Winter Olympics, two of the largest sporting categories where men and women have both competed over the last half century. As with the aggregate estimations, GDP per capita is more important for the Winter Games than Summer Games. We can see that the coefficients on per capita income are also larger for men than for women in both sports. Being from a country that gets heavy frost is much more important for success in skiing events than skating events, which makes intuitive sense (one can build a skating rink but not a snowy mountain). Being from the communist bloc has aided female athletes more in skating, but male athletes more in skiing. Unlike the results from the Summer Games, where the home bias helps in judged competitions, there appears to be no host advantage in men's and women's skating.[23]

CONCLUSIONS

The Olympics as we know them today are a far cry from their aristocratic and largely European male roots. In line with other studies, we find that determinants such as income, country size, status as a current host, and inclusion in the communist bloc have generally been historically significant determinants of both female and male success. But a clear narrative thread is also couched in the pluralization of Olympic competition throughout the postwar period. At the Winter Games, which are not drastically different from the 1960s in terms of their geographical makeup, success is still largely associated with being from a rich, large country with a snowy climate. In contrast, the Summer Games, where geographic pluralization has been much more comprehensive, exhibit more subtle determinants of success reflective of their diversity. Rather than income, education is a much more robust positive dominant of medal winnings, and this appears to have been far more important for women than men. Moreover, the statistical models reveal that at the Summer Games even these determinants are waning in their influence: As medal winnings become more diversified over time, smaller, poorer, even possibly less educated countries face lower hurdles to achieving success.

Similar trends are evident in the event-specific models. In sports that require large capital expenditures on infrastructure such as aquatics, large, rich, and more educated countries have done better compared with smaller nations, which face significant barriers to entry. However, events that are more

22. We are indebted to one of the anonymous referees for suggesting this linkage.

23. This could be because our medaling values for skating aggregate both speed skating, an objectively judged sport, and individual figure skating, which is subjectively judged. Balmer, Nevill, and Williams (2001) found some evidence of home-country advantage for figure skating events but no advantage for speed skating.

universally accessible, such as athletics and boxing, evidence significantly less handicap for small, poor countries.[24] Having the "home-field" may be more advantageous for judged sports such as gymnastics, as is (or at least was) the case for being from the communist bloc. East Germany, during the height of its doping years, unduly benefited within nonjudged events such as aquatics and athletics, where strength and stamina mattered comparatively more. The distortive impact of the East German doping program was particularly profound in women's events.

Decades ago, the Summer Games were an old boys' club; by many measures the Winter Games still are. Now, however, this old boys' club must compete with talented athletes from almost every country on earth, large and small, rich and poor, many of whom have found their comparative sporting niches. Looking forward, the image of the incumbent champion— rich, European, and male—will become ever more antiquated. The results in this paper suggest that in events such as athletics an increasingly diverse set of countries is likely to experience success, but this growing pluralism of outcomes will come more slowly in the Winter Games, events that require significant capital investments, and in judged contests.

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24. We do not show boxing estimations in table 8 for reasons already discussed. However, running negative binomial regressions of men's boxing yields insignificant results on the GDP per capita coefficient, just as in the case of athletics.

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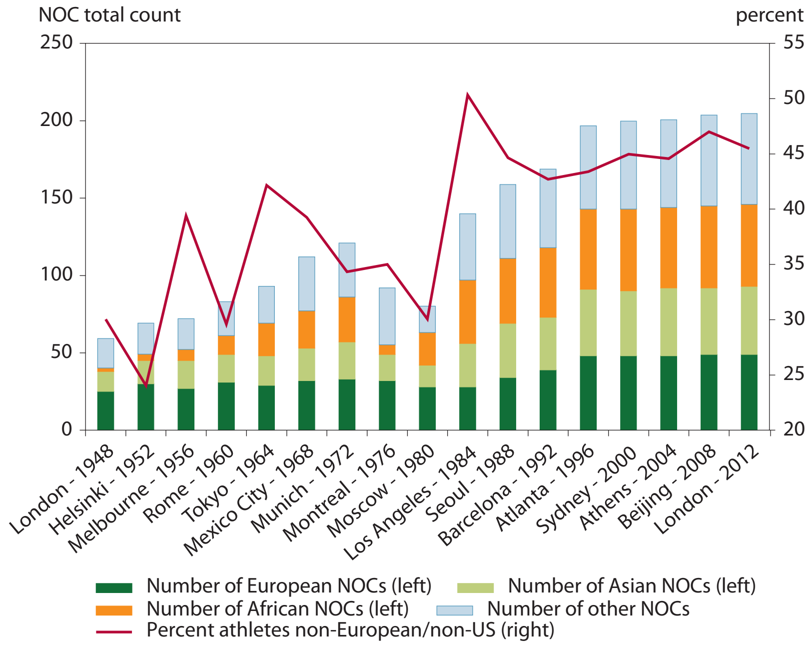
Figure 1 Growing pluralism at the Summer Olympic Games, 1948–2012

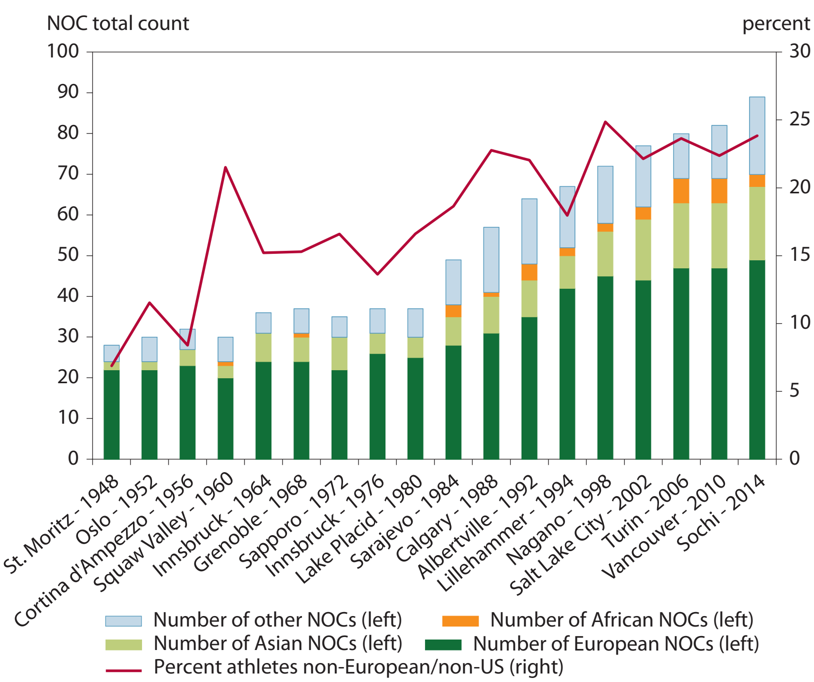


NOC = National Olympic Committee

Note: 1956 Games do not include data on equestrian events.

Source: International Olympic Committee.

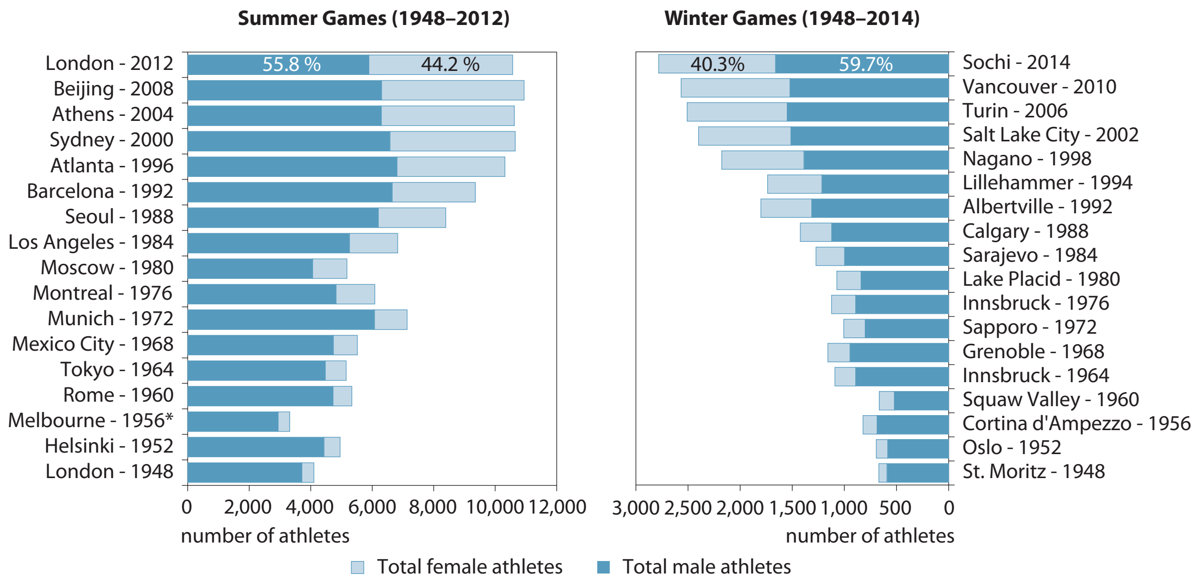
Figure 2 Growing pluralism at the Winter Olympic Games, 1948–2014



NOC = National Olympic Committee

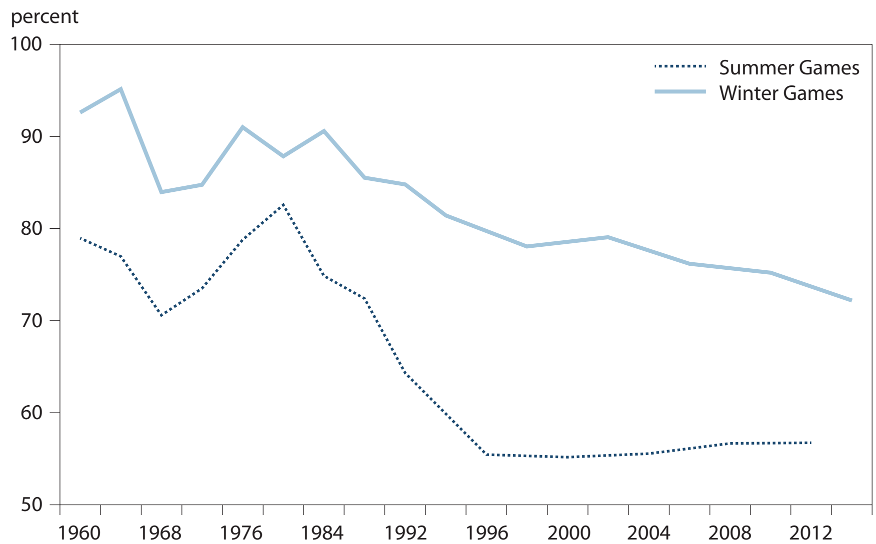
Source: International Olympic Committee.

Figure 3 Female athletic inclusion at the Olympic Games, 1948–2014



* = For Melbourne - 1956, information on equestrian games not included.
Source: International Olympic Committee.

Figure 4 Share of total medals won by top 10 performers at the Olympics, 1960–2014



Note: "Top 10" refers to the top 10 ranked National Olympic Committees in terms of total medals won at each individual Olympic Games.
Source: International Olympic Committee.

Table 1 Most successful countries in terms of average winnings at the Olympic Games (percent)

Summer Games, 1960–2012				
Rank	**National Olympic Committee**	**Average total medal share**	**Average male medal share**	**Average female medal share**
1	Soviet Union	20.6	20.6	23.9
2	United States	14.7	13.7	16.7
3	East Germany	12.8	9.1	25.0
4	Unified team of Germany	9.5	8.0	13.2
5	Russia	8.6	8.7	8.9
6	China	6.7	4.9	10.0
7	West Germany	6.4	5.4	6.2
8	Germany	6.3	6.0	5.9
9	Japan	3.6	4.2	2.3
10	Australia	3.6	3.1	4.7
11	Great Britain	3.5	3.4	3.1
12	Italy	3.5	4.0	2.0
13	Hungary	3.5	4.0	2.8
14	France	3.0	3.4	2.0
15	Romania	2.9	2.1	5.2
Winter Games, 1960–2010				
Rank	**National Olympic Committee**	**Average total medal share**	**Average male medal share**	**Average female medal share**
1	Soviet Union	20.4	17.4	22.7
2	East Germany	15.6	13.0	18.3
3	Germany	13.5	9.4	18.3
4	Norway	9.9	14.4	4.5
5	Unified team of Germany	9.3	8.0	9.4
6	United States	8.7	7.0	11.6
7	Russia	8.3	6.2	8.8
8	Austria	7.3	8.5	5.6
9	Finland	5.8	6.8	5.4
10	West Germany	5.7	5.1	5.6
11	Canada	4.9	4.0	5.8
12	Switzerland	4.7	5.8	3.7
13	Sweden	4.4	5.7	2.7
14	Italy	4.3	4.6	3.3
15	Netherlands	4.0	4.3	4.2

Notes: Countries are ranked according to the arithmetic average value of total medal shares over all performances at the Olympic Games between 1960 and 2012 (Summer) or 1960 and 2010 (Winter). Total medal shares also include medals in mixed-gender events, which are not shown in the table.

Source: International Olympic Committee.

Table 2 Correlates of success at the Olympic Games, 1960–2012

Variable	Summer Games, 1960–2012: Total medal share	Summer Games, 1960–2012: Female medal share	Summer Games, 1960–2012: Male medal share	Winter Games, 1960–2010: Total medal share	Winter Games, 1960–2010: Female medal share	Winter Games, 1960–2010: Male medal share
Current host	0.31	0.25	0.31	0.21	0.15	0.22
Post host	0.16	0.11	0.16	0.11	**0.04**	0.12
Communist bloc	0.37	0.37	0.36	0.18	0.18	0.13
Population	0.31	0.31	0.29	0.12	0.18	**0.06**
Small state	–0.13	–0.12	–0.14	–0.08	**–0.07**	–0.07
Landlocked	–0.11	–0.10	–0.11	**–0.05**	**–0.08**	**–0.02**
GDP per capita (PPP)	0.29	0.22	0.29	0.33	0.20	0.37
Total years schooling	0.31	0.26	0.31	0.20	0.11	0.19
Percent population tertiary complete	0.30	0.25	0.29	0.12	**0.08**	0.09
Labor force gender ratio	0.13	0.13	0.11	0.19	0.16	0.18
Percent population Muslim	–0.16	–0.12	–0.15	–0.16	–0.09	–0.16
Adolescent fertility	–0.21	–0.16	–0.22	–0.22	**–0.07**	–0.24
Percent population urban	0.18	0.14	0.18	0.10	**0.05**	0.12
Distance from equator	0.31	0.24	0.33	0.35	0.20	0.39
Frost dummy (Winter Games only)	n.a.	n.a.	n.a.	0.20	**0.06**	0.22

n.a. = not applicable

Notes: Shaded correlation coefficients not statistically significant at the 95 percent level. Each coefficient uses pairwise correlations, meaning that sampling size differs across variables. Labor force gender ratio only includes post-1996 observations due to lack of prior data.

Table 3 Determinants of success at the Summer Games (tobit), 1960–2012

Variable	Male-event medal shares, 1960–2012			Female-event medal shares, 1960–2012		
Dependent variable: Male/ female medal shares	**(3.1) Tobit**	**(3.2) Tobit w/ LDV**	**(3.3) Random effects tobit**	**(3.4) Tobit**	**(3.5) Tobit w/ LDV**	**(3.6) Random effects tobit**
Log GDP per capita (1990 G-K $I)	0.123 (0.118)	0.101** (0.0488)	0.558*** (0.146)	0.358 (0.246)	0.303** (0.124)	0.802** (0.349)
Log population	1.283*** (0.109)	0.226*** (0.0351)	0.947*** (0.127)	2.084*** (0.191)	0.625*** (0.0958)	1.865*** (0.220)
Current host	4.638*** (1.632)	2.487*** (0.721)	3.361*** (0.306)	5.222*** (1.675)	2.804*** (0.819)	3.692*** (0.634)
Post host	1.782*** (0.614)	−1.379*** (0.505)	1.008*** (0.333)	1.144 (0.725)	−1.852* (0.957)	0.0636 (0.717)
Average years total schooling	0.614*** (0.0689)	0.0917*** (0.0216)	0.299*** (0.0612)	1.326*** (0.156)	0.382*** (0.0685)	0.851*** (0.140)
Distance from equator	0.0366*** (0.00611)	0.0118*** (0.00276)	0.0381*** (0.0132)	0.0190 (0.0118)	0.00925 (0.00631)	0.0459** (0.0226)
Communist bloc	2.468*** (0.429)	0.722*** (0.181)	2.240*** (0.288)	4.901*** (0.640)	2.003*** (0.440)	3.667*** (0.590)
East German "doping" dummy	5.243*** (1.868)	−0.930 (1.525)	4.897*** (0.994)	17.653*** (6.795)	−2.332 (2.034)	17.821*** (2.062)
Lagged dependent variable	n.a.	0.880*** (0.0499)	n.a.	n.a.	0.733*** (0.0666)	n.a.
Constant	−29.36*** (2.341)	−6.191*** (0.783)	−24.50*** (2.480)	−52.07*** (4.727)	−17.73*** (2.258)	−48.50*** (4.614)
Sigma	2.303*** (0.166)	0.940*** (0.0788)	2.000*** (0.150)	3.565*** (0.276)	1.836*** (0.165)	2.703*** (0.249)
Observations	1,376	1,159	1,376	1,123	916	1,123
Unique country groups	n.a.	n.a.	131	n.a.	n.a.	131
Time controls	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Country controls	**No**	**No**	**No**	**No**	**No**	**No**

w/ LDV = with lagged dependent variable; G-K $1 = Geary-Khamis international dollar; n.a. = not applicable

Notes: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1, except in case of random effects tobit. East German doping dummy estimated as 1 for East Germany between years 1976 and 1988. A fixed effect dummy used to denote East Germany over all observations and a dummy variable for the boycotted 1980/1984 Games are also included in all regressions but not reported.

Source: Authors' calculations.

Table 4 Determinants of success at the Winter Games (tobit), 1960–2010

Variable	Male–event medal shares, 1960–2010			Female–event medal shares, 1960–2010		
Dependent variable: Male/ female medal shares	**(4.1) Tobit**	**(4.2) Tobit w/ LDV**	**(4.3) Random effects tobit**	**(4.4) Tobit**	**(4.5) Tobit w/ LDV**	**(4.6) Random effects tobit**
Log GDP per capita (1990 G-K $I)	8.755*** (0.895)	4.095*** (0.602)	7.141*** (1.234)	6.757*** (0.961)	4.181*** (0.724)	6.604*** (1.485)
Log population	2.070*** (0.311)	0.838*** (0.178)	2.732*** (0.533)	3.511*** (0.425)	1.333*** (0.291)	3.996*** (0.649)
Current host	2.790* (1.512)	3.379*** (1.072)	3.271*** (0.991)	1.995 (1.917)	0.559 (1.469)	2.232 (1.377)
Post host	0.331 (1.575)	–1.533 (1.184)	0.508 (1.006)	–0.384 (1.493)	–2.195* (1.284)	–0.533 (1.368)
Average years total schooling	–0.131 (0.219)	–0.0195 (0.151)	–0.289 (0.372)	0.441 (0.296)	–0.152 (0.236)	0.122 (0.491)
Distance from equator	0.306*** (0.0466)	0.0989*** (0.0273)	0.301*** (0.0847)	0.322*** (0.0539)	0.127*** (0.0373)	0.341*** (0.106)
Communist bloc	3.349*** (1.269)	1.684** (0.749)	0.527 (1.485)	3.209* (1.743)	1.212 (1.257)	–0.967 (1.990)
East German "doping" dummy	7.290** (3.353)	–6.140*** (1.965)	7.102** (2.984)	21.697*** (4.616)	5.160 (3.335)	21.491*** (4.043)
Lagged dependent variable	n.a.	0.795*** (0.0548)	n.a.	n.a.	0.720*** (0.112)	n.a.
Winter frost dummy	6.275*** (0.741)	2.703*** (0.512)	7.203*** (1.717)	4.253*** (0.979)	2.538*** (0.753)	6.072*** (2.081)
Constant	–137.2*** (11.18)	–61.41*** (6.772)	–130.8*** (15.59)	–147.7*** (15.16)	–70.22*** (9.122)	–152.4*** (19.21)
Sigma	5.389*** (0.326)	3.461*** (0.247)	4.050*** (0.558)	6.646*** (0.553)	4.753*** (0.367)	4.870*** (0.710)
Observations	593	486	593	454	366	454
Unique country groups	n.a.	n.a.	78	n.a.	n.a.	64
Time controls	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Country controls	**No**	**No**	**No**	**No**	**No**	**No**

w/ LDV = with lagged dependent variable; G-K $1 = Geary-Khamis international dollar; n.a. = not applicable

Notes: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1, except in case of random effects tobit. East German doping dummy estimated as 1 for East Germany between years 1976 and 1988. A fixed effect dummy used to denote East Germany over all observations is also included in all regressions but not reported.

Source: Authors' calculations.

Table 5 Mostly diminishing effects of socioeconomic determinants over time

Model	Dependent variable	GDP per capita interaction	Population interaction	Education interaction	Host interaction	Distance from equator interaction	Communist bloc interaction
Summer Games, 1960–2012							
Tobit	Male medal shares	0.0220 (0.0224)	**–0.0885***** **(0.0238)**	0.0104 (0.00929)	–0.144 (0.218)	**0.00268**** **(0.00112)**	**–0.266**** **(0.108)**
	Female medal shares	**–0.136**** **(0.0617)**	**–0.211***** **(0.0483)**	**–0.0796***** **(0.0252)**	–0.171 (0.269)	3.92e–05 (0.00213)	**–0.426**** **(0.166)**
Tobit w/ LDV	Male medal shares	**0.0223**** **(0.00942)**	–0.00892 (0.00665)	**0.00609*** **(0.00334)**	–0.0570 (0.130)	**0.00105**** **(0.000505)**	**–0.0718**** **(0.0307)**
	Female medal shares	–0.0195 (0.0354)	**–0.0520*** **(0.0287)**	–0.0114 (0.0141)	–0.268 (0.180)	0.00141 (0.00125)	–0.102 (0.0747)
Random effects tobit	Male medal shares	0.0101 (0.0119)	**–0.0388***** **(0.00812)**	0.00318 (0.00448)	–0.0796 (0.0755)	0.000973 (0.000666)	**0.186***** **(0.0501)**
	Female medal shares	**–0.104**** **(0.0427)**	**–0.119***** **(0.0228)**	**–0.0572***** **(0.0156)**	–0.216 (0.157)	–0.000161 (0.00198)	–0.0342 (0.110)
Winter Games, 1960–2010							
Tobit	Male medal shares	–0.0197 (0.177)	0.0775 (0.0718)	**0.107**** **(0.0477)**	–0.0772 (0.321)	**–0.0233**** **(0.00935)**	0.122 (0.326)
	Female medal shares	–0.304 (0.201)	–0.0817 (0.0922)	0.0682 (0.0603)	**–1.007**** **(0.391)**	–0.00820 (0.00845)	–0.0341 (0.449)
Tobit w/ LDV	Male medal shares	–0.156 (0.149)	0.0493 (0.0468)	**0.0594*** **(0.0338)**	–0.0390 (0.235)	–0.00744 (0.00621)	0.194 (0.202)
	Female medal shares	**–0.395*** **(0.219)**	0.0646 (0.0739)	0.0799 (0.0616)	–0.572 (0.392)	–0.0101 (0.00738)	0.521 (0.383)
Random effects tobit	Male medal shares	0.0801 (0.163)	**0.128***** **(0.0443)**	**0.0890**** **(0.0395)**	0.285 (0.236)	**–0.0219***** **(0.00595)**	0.337 (0.274)
	Female medal shares	–0.0727 (0.217)	–0.0650 (0.0585)	0.0300 (0.0543)	**–0.543*** **(0.322)**	–0.00724 (0.00830)	–0.0510 (0.352)

w/ LDV = with lagged dependent variable

Notes: Standard errors in parentheses are heteroskedastistically robust, except in case of random effects tobit; *** p<0.01, ** p<0.05, * p<0.1. Each regression is estimated according to the parameters in tables 3 and 4, although these coefficients are not reported here. Each interaction effect is tested individually in separate estimations. Cells in bold represent interaction effects that were statistically significant at at least 10 percent.

Source: Authors' calculations.

Table 6 Medal-winning concentrations ranked by sport in the Summer Games, 1960–2012

Sport	Gender category	Herfindahl index of medaling	Top country, by share of medals won	Cumulative share of top 5 countries (percent)
Shooting	Women	0.063	China (16%)	46
	Men	0.047	China (10%)	40
Sailing	Women	0.060	Netherlands (11%)	44
	Men	0.053	Great Britain (11%)	42
Taekwondo	Women	0.061	South Korea (13%)	41
	Men	0.062	South Korea (13%)	45
Canoeing/Kayaking	Women	0.071	Hungary (17%)	48
	Men	0.053	Hungary (12%)	42
Cycling	Women	0.072	Netherlands (11%)	51
	Men	0.056	France (9%)	43
Athletics	Women	0.053	USA (13%)	44
	Men	0.075	USA (24%)	49
Rowing	Women	0.079	Romania (16%)	52
	Men	0.050	East Germany (10%)	39
Weightlifting	Women	0.077	China (18%)	52
	Men	0.059	USSR (13%)	46
Judo	Women	0.087	Japan (16%)	57
	Men	0.056	Japan (14%)	44
Boxing	Women	0.121	USA/Russia/China (17%)	67
	Men	0.040	Cuba (11%)	37
Wrestling	Women	0.117	Japan (25%)	64
	Men	0.051	USSR (12%)	41
Tennis	Women	0.128	USA (28%)	67
	Men	0.078	USA (15%)	50
Handball	Women	0.121	South Korea (20%)	67
	Men	0.086	Romania/Sweden (12%)	52

(continued)

Table 6 Medal-winning concentrations ranked by sport in the Summer Games, 1960–2012 *(continued)*

Sport	**Gender category**	**Herfindahl index of medaling**	**Top country, by share of medals won**	**Cumulative share of top 5 countries** (percent)
Volleyball	Women	0.118	Brazil (19%)	70
	Men	0.093	Brazil (19%)	61
Fencing	Women	0.100	Italy (20%)	58
	Men	0.115	France (19%)	69
Aquatics	Women	0.111	USA (28%)	62
	Men	0.133	USA (33%)	60
Football	Women	0.189	USA (33%)	87
	Men	0.061	Brazil (12%)	44
Gymnastics	Women	0.134	USSR (22%)	73
	Men	0.117	Japan (22%)	63
Hockey	Women	0.129	Netherlands (26%)	67
	Men	0.129	Australia (21%)	71
Basketball	Women	0.152	USA (30%)	70
	Men	0.153	USA (31%)	76
Archery	Women	0.240	South Korea (43%)	74
	Men	0.117	USA/South Korea (20%)	67
Modern Pentathlon	Women	0.222	Great Britain (42%)	75
	Men	0.139	Hungary (26%)	67
Triathlon	Women	0.262	Australia (42%)	92
	Men	0.167	New Zealand (25%)	83
Softball/Baseball	Women	0.290	USA (33%)	100
	Men	0.219	Cuba (33%)	93
Badminton	Women	0.366	China (58%)	92
	Men	0.237	Indonesia (32%)	100
Table Tennis	Women	0.375	China (59%)	95
	Men	0.299	China (48%)	93

Notes: "Top country" and "cumulative share" columns calculate share of all medals that were available in sporting category in all Olympic Games 1960–2012 won by NOC. In case of a tie in the "top country" column, all relevant countries are shown, and percentage indicates medal share of each country separately. Table ranked from least concentrated to most concentrated according to average of male and female Herfindahl index score.

Source: International Olympic Committee.

Table 7 Medal-winning concentrations ranked by sport in the Winter Games, 1960–2010

Sport	Gender category	Herfindahl index of medaling	Top country, by share of medals won	Cumulative share of top 5 countries (percent)
Skiing	Women	0.062	Austria/Norway (9%)	41
	Men	0.085	Norway (17%)	57
Skating	Women	0.096	USA (17%)	59
	Men	0.103	Netherlands (17%)	65
Biathlon	Women	0.195	Germany (36%)	75
	Men	0.118	Norway (21%)	68
Bobsleigh	Women	0.211	Germany/USA (28%)	94
	Men	0.130	Switzerland (24%)	72
Luge	Women	0.222	Germany/East Germany (31%)	90
	Men	0.153	East Germany (23%)	79
Ice Hockey	Women	0.274	USA/Canada (33%)	100
	Men	0.136	USSR (19%)	74
Curling	Women	0.218	Canada (33%)	92
	Men	0.252	Canada (33%)	100

Notes: "Top country" and "cumulative share" columns calculate share of all medals that were available in sporting category in all Olympic Games 1960–2010 won by NOC. In case of a tie in the "top country" column, all relevant countries are shown, and percentage indicates medal share of each country separately. Table ranked from least concentrated to most concentrated according to average of male and female Herfindahl index score.

Source: International Olympic Committee.

Table 8 Sports-specific determinants of success at the Summer Games (negative binomial models)

Sporting category/period	Regression	Log population	Log GDP per capita	Current host	Communist bloc	Average years schooling	Doping dummy	Boycott dummy	Labor force ratio	Distance from equator	Observations
Full sample (1960–2012)											
Aquatics	Male medal shares	0.833***	0.634***	0.739*	0.533**	0.462***	–0.139	1.469***	n.a.	0.00172	903
	Female medal shares	0.812***	0.128	0.760**	0.561	0.592***	1.983***	1.396***		0.0124	733
Athletics	Male medal shares	0.528***	–0.118	0.679**	0.215	0.312***	0.768*	1.065***	n.a.	0.000773	1,264
	Female medal shares	0.474***	–0.130	0.975**	1.132***	0.425***	1.292*	1.115***		0.000108	986
Gymnastics	Male medal shares	0.827***	–0.672***	0.932***	0.0378	0.380***	1.234*	0.765	n.a.	0.0238***	353
	Female medal shares	0.528***	–1.866***	0.964*	2.857***	1.172***	–0.743	0.496		–0.0175	378
Modern sample (1996–2012)											
Aquatics	Male medal shares	0.832***	0.491***	1.087**	0.289	0.474***	n.a.	n.a.	0.0105	0.000389	486
	Female medal shares	0.813***	0.140	0.903**	0.0209	0.588***			0.0396**	–0.00498	412
Athletics	Male medal shares	0.481***	–0.0643	0.501	0.145	0.316***	n.a.	n.a.	0.0115*	–0.00805	596
	Female medal shares	0.455***	–0.197	1.333*	0.263	0.469***			0.0113	–0.00862	548
Canoeing/Kayaking	Male medal shares	0.439***	–0.294	0.342	0.0485	0.461***	n.a.	n.a.	–0.00327	0.0319**	218
	Female medal shares	0.223**	–0.253	–0.0981	–14.80***	0.378***			–0.0306	0.0312*	148
Cycling	Male medal shares	0.654***	1.662***	0.824	–24.34***	–0.147	n.a.	n.a.	0.0580***	–0.00152	261
	Female medal shares	0.561***	0.867***	0.340	–0.545	0.0348			0.0341	0.00924	180
Fencing	Male medal shares	0.633***	0.237	–2.439***	1.263**	0.278**	n.a.	n.a.	–0.0218	0.0264	157
	Female medal shares	0.695***	0.342	–1.766**	–0.320	0.0561			–0.00490	0.0351*	140
Gymnastics	Male medal shares	0.626***	–0.652***	0.977***	–0.217	0.233***	n.a.	n.a.	0.00429	0.0278**	154
	Female medal shares	0.960***	–1.646***	1.060*	–1.602**	0.645***			0.0949***	–0.0243	177
Judo	Male medal shares	0.516***	0.0380	–1.289	0.360	0.352***	n.a.	n.a.	0.00194	0.00662	322
	Female medal shares	0.328***	1.058***	–0.505	3.424***	0.313***			–0.0318***	–0.00123	224
Rowing	Male medal shares	0.179**	1.380***	1.153***	–16.02***	–0.115	n.a.	n.a.	0.0415**	–0.00243	223
	Female medal shares	0.241***	0.274	0.794*	–0.598	0.188**			0.0774***	–0.00130	164
Shooting	Male medal shares	0.604***	0.134	0.339	0.779*	0.234***	n.a.	n.a.	0.00422	0.0380***	323
	Female medal shares	0.484***	–0.578***	0.0291	1.240***	0.431***			0.0116	0.0341***	223
Taekwondo	Male medal shares	0.440***	0.504*	1.107***	0.0204	0.198**	n.a.	n.a.	–0.0396***	0.00362	154
	Female medal shares	0.241***	0.485*	0.208	1.347***	0.0841			–0.00315	–0.00496	139
Weightlifting	Male medal shares	0.327***	–0.228	0.0292	1.192***	0.0498	n.a.	n.a.	0.00190	0.0451***	245
	Female medal shares	0.523***	–0.328	–0.0938	–0.0883	0.0312			0.0296*	0.0279*	149

n.a. = not applicable

Notes: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1. All regressions are negative binomial models with year controls and use total medal counts as a dependent variable. Coefficients on constant term, year dummies, and East German fixed effect not reported. All estimations only use observations in which NOC reports 1 or more female/male competitors in given sporting category. Cells shaded in grey designate coefficients that are significantly different at at least a 10 percent statistical level using a linear Wald test and adjusted for country-specific clustered errors.

Source: Authors' calculations.

Table 9 Sports-specific determinants of success at the Winter Games (negative binomial models)

Variable	Skating (1960–2010)		Skiing (1960–2010)	
Dependent variable: Male/ female total medal counts	**(9.1) Male**	**(9.2) Female**	**(9.3) Male**	**(9.4) Female**
Log GDP per capita (1990 G-K $I)	1.129*** (0.248)	0.674*** (0.246)	2.534*** (0.266)	1.518*** (0.252)
Log population	0.664*** (0.0799)	0.858*** (0.0833)	0.405*** (0.0746)	0.465*** (0.0804)
Current host	0.262 (0.349)	0.0497 (0.328)	0.698** (0.278)	0.149 (0.387)
Post host	–0.301 (0.381)	–1.525*** (0.543)	0.247 (0.309)	–0.141 (0.291)
Average years total schooling	0.391*** (0.0860)	0.327*** (0.0812)	–0.278*** (0.0567)	–0.0825 (0.0619)
Distance from equator	0.0716*** (0.0130)	0.0616*** (0.0125)	0.0801*** (0.0114)	0.0495*** (0.0110)
Winter frost dummy	0.123 (0.283)	–0.254 (0.300)	1.827*** (0.215)	1.207*** (0.217)
Communist bloc	0.472 (0.327)	0.804** (0.321)	0.950*** (0.334)	0.376 (0.397)
East German "doping" dummy	17.87*** (0.917)	3.836*** (0.939)	0.372 (0.617)	19.44*** (0.668)
Constant	–30.61*** (2.777)	–27.87*** (2.873)	–33.52*** (2.571)	–24.92*** (2.394)
Sigma	0.630*** (0.181)	–0.0162 (0.342)	0.152 (0.159)	0.178 (0.185)
Observations	358	340	538	392
Time controls	**Yes**	**Yes**	**Yes**	**Yes**
Country controls	**No**	**No**	**No**	**No**

Notes: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1. All regressions are negative binomial models with year controls and use total medal counts as a dependent variable. All estimations only use observations in which NOC reports 1 or more females/male competitors in given sporting category. Cells shaded in grey designate coefficients that are significantly different at at least a 10 percent statistical level using a linear Wald test and adjusted for country-specific clustered errors.

Source: Authors' calculations.

APPENDIX A

Appendix table A.1 Alternate estimations of determinants of success at the Summer Games (OLS/fixed effects)

Variable	Male-event medal shares, 1960–2012			Female-event medal shares, 1960–2012		
Dependent variable: Male/ female medal shares	**(APP1.1) OLS**	**(APP1.2) OLS w/ LDV**	**(APP1.3) Country fixed effects**	**(APP1.4) OLS**	**(APP1.5) OLS w/ LDV**	**(APP1.6) Country fixed effects**
Log GDP per capita (1990 G-K $I)	–0.0540 (0.0562)	–0.00644 (0.0228)	0.127 (0.130)	–0.255*** (0.0902)	–0.0213 (0.0389)	0.415** (0.198)
Log population	0.606*** (0.0629)	0.0267 (0.0238)	0.127 (0.255)	0.843*** (0.0970)	0.168*** (0.0414)	–0.113 (0.352)
Current host	5.504*** (1.858)	2.535*** (0.734)	3.267*** (0.760)	5.784*** (2.199)	2.569*** (0.832)	2.931*** (0.672)
Post host	2.455*** (0.795)	–1.441*** (0.546)	0.937 (0.624)	1.823* (0.937)	–1.914** (0.926)	–0.341 (0.868)
Average years total schooling	0.288*** (0.0395)	0.0109 (0.0125)	0.167* (0.0886)	0.463*** (0.0637)	0.0736*** (0.0231)	0.293** (0.139)
Distance from equator	0.00683** (0.00281)	–0.000158 (0.00133)	n.a.	–0.00521 (0.00457)	–0.00151 (0.00276)	n.a.
Communist bloc	2.211*** (0.435)	0.505*** (0.166)	1.919*** (0.423)	2.737*** (0.561)	0.811** (0.363)	2.110*** (0.430)
East German "doping" dummy	4.906*** (1.900)	–1.054 (1.607)	4.745*** (0.151)	17.53*** (6.757)	–3.012 (1.862)	17.45*** (0.322)
Lagged dependent variable		0.913*** (0.0490)			0.781*** (0.0657)	
Constant	–9.862*** (0.953)	–0.413 (0.476)	–2.799 (4.429)	–12.74*** (1.444)	–2.740*** (0.773)	–1.679 (6.348)
Observations	1,376	1,159	1,376	1,123	916	1,123
R-Squared	0.482	0.917	0.285	0.535	0.883	0.266
Unique country groups	n.a.	n.a.	131	n.a.	n.a.	131
Time controls	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Country controls	**No**	**No**	**No**	**No**	**No**	**No**

OLS = ordinary least squares; w/ LDV = with lagged dependent variable; G-K $1 = Geary-Khamis international dollar; n.a. = not applicable

Notes: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1. East German doping dummy estimated as 1 for East Germany between years 1976 and 1988. A fixed effect dummy used to denote East Germany over all observations and a dummy variable for the boycotted 1980/1984 games are also included in all regressions but not reported.

Source: Authors' calculations.

Appendix table A.2 Alternate estimations of determinants of success at the Winter Games (OLS/fixed effects)

Variable	Male-event medal shares, 1960–2010			Female-event medal shares, 1960–2010		
Dependent variable: Male/ female medal shares	**(APP2.1) OLS**	**(APP2.2) OLS w/ LDV**	**(APP2.3) Country fixed effects**	**(APP2.4) OLS**	**(APP2.5) OLS w/ LDV**	**(APP2.6) Country fixed effects**
Log GDP per capita (1990 G-K $I)	1.409*** (0.257)	0.396* (0.220)	1.395** (0.591)	1.044*** (0.382)	0.805** (0.359)	2.420*** (0.577)
Log population	0.482*** (0.141)	0.138 (0.0913)	2.012 (1.338)	1.622*** (0.225)	0.571*** (0.168)	2.123 (2.435)
Current host	3.636** (1.494)	3.285*** (1.143)	2.962** (1.130)	2.278 (1.435)	0.635 (1.154)	1.916*** (0.580)
Post host	1.108 (1.404)	–1.400 (0.951)	0.321 (0.930)	–0.913 (0.854)	–2.355** (0.956)	–1.217 (0.986)
Average years total schooling	–0.00106 (0.101)	0.0543 (0.0786)	–0.287 (0.222)	0.505*** (0.171)	0.137 (0.145)	–0.195 (0.238)
Distance from equator	0.0553*** (0.0145)	0.00730 (0.0106)	n.a.	0.102*** (0.0239)	0.0373* (0.0192)	n.a.
Communist bloc	–0.415 (0.665)	–0.0381 (0.361)	–0.327 (0.672)	0.807 (0.944)	0.295 (0.671)	–0.955 (0.884)
East German "doping" dummy	6.721** (3.231)	–5.899*** (1.788)	6.844*** (0.491)	20.60*** (4.372)	6.408** (3.084)	20.31*** (0.777)
Lagged dependent variable	n.a.	0.760*** (0.0469)	n.a.	n.a.	0.621*** (0.101)	n.a.
Winter frost dummy	1.945*** (0.357)	0.590** (0.288)	n.a.	0.885* (0.522)	0.530 (0.458)	n.a.
Constant	–20.33*** (2.519)	–6.162*** (2.003)	–41.77* (24.58)	–42.09*** (4.961)	–17.92*** (4.451)	–54.11 (40.19)
Observations	593	486	596	454	366	457
Unique country groups	n.a.	n.a.	79	n.a.	n.a.	65
Time controls	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Country controls	**No**	**No**	**No**	**No**	**No**	**No**

OLS = ordinary least squares; w/ LDV = with lagged dependent variable; G-K $1 = Geary-Khamis international dollar; n.a. = not applicable

Notes: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1. East German doping dummy estimated as 1 for East Germany between years 1976 and 1988. A fixed effect dummy used to denote East Germany over all observations is also included in all regressions but not reported.

Source: Authors' calculations.