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A Tale of Two Seasons: Participation and Medal Counts at the Summer and Winter Olympic Games

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A Tale of Two Seasons: Participation and Medal Counts at the Summer and Winter Olympic Games

By

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Abstract
This paper examines the post-War Summer and Winter Olympic Games in order to determine the economic and political determinants of national participation, of female participation in particular, and of success at the Games (i.e., medal counts). Compared to the Summer Games, Winter participation levels are driven more by income and less by population, have less host nation bias and a greater effect of climate. Roughly similar factors determine medal count success, although single party and communist regimes win far more medals (and gold medals) in both seasons than can be attributed to other factors. We find no large significant differences between types of athletic events (e.g. luge versus nordic skiing). We estimate that major participating nations requires a $260 rise in income per capita to send an extra participant. Similarly the "cost" of an extra medal is $1700 per capita and $4750 per capita for an additional gold medal. Predictions for participation and medal counts (including gold medals in particular) for the 2002 Salt Lake City Games are presented as a test of our analysis.

JEL codes: A1 ----General Economics

F0 ---- International Economics

J0 ---- Labor and Demographic Economics

O1 --- Economic Development

Z10 -- Cultural Economics

Contents

A Tale of Two Seasons: Participation and Medal Counts at the Summer and Winter Olympic Games[1]

I. Introduction

The Olympic movement celebrates a spirit of international competition, of global athletic excellence. Yet not all nations have an equal ability to participate in the Games, nor do they have an equal ability to win medals if they do participate. In the Winter Games, this is especially true. The 1998 Winter Games boasted participation by an impressive 2077 athletes from 72 nations, but those numbers pale beside more than 12000 athletes from roughly 200 nations at the 2000 Summer Games. Furthermore, in the entire history of the Winter Olympics, no athlete or team from a snowless nation has ever placed higher than fourteenth in an event. In fact, only two teams have ever finished in the top half of the field (Wallechinsky, 2001). While the reason may seem obvious, the inequality bears closer inspection for the root causes, and the similarity between Summer and Winter Games.

This paper investigates the economic and political factors that encourage nations to send Olympic athletes, then analyzes determinants of their success. It does not intend to minimize the primary importance of athletic excellence, but offers insight into the variables that affect an athlete's ability to

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participate and to succeed. In particular, it is meant to compare with previous literature that explores the same question, although to our knowledge this is the first piece which compares the Summer and Winter Games.

Intuition suggests that several key political and economic variables have an important impact on national participation and success. Although our list is not exhaustive, many other variables are highly correlated with our chosen variables, so are not included to avoid collinearity (and their effects are reflected in our list of variables, at any rate). High productive capacity or income per person (measured by GDP per capita) displays an ability to pay the costs necessary to send athletes to the Games, and may also be associated with a higher quality of training and better equipment. A large population means more effective sharing of the fixed costs of training (e.g. infrastructure and facilities), and a larger pool of potential athletes from which to select successful contenders. Obviously, the hosting nation and its neighbors have advantages in terms of lower transportation costs, and climatic and training advantages in the competitions themselves. Especially for the Winter Games, we suspect that climate (and latitude, as the two are tightly related) play a critical role. Finally, the analysis also hypothesizes that political structure has an effect on participation and success. Single-party or Communist systems may have a different approach to participation, training and incentives for success so may show different results.

Section II describes the data and some salient characteristics of the post-War Games. Section III analyses the number of athletes participating from each possible nation, and includes predictions for the 2002 Salt Lake City Games as well as inferred "costs" of participating for a selection of nations. To our knowledge, no other published paper has tackled this issue. Section IV uses several different techniques to analyze medal-winning success, presenting estimates that mirror the variable choice and models used elsewhere in the literature (Ball, 1972; Levine, 1974; Condon et al., 1999; Bernard and

Busse, 2000; Johnson and Ali, 2000). This section concludes with predictions for the 2002 Salt Lake City Games, as well as an estimate of the "cost" of an Olympic medal for major participating nations. Section V addresses differences between types of athletic events. Section VI summarizes our conclusions and offers some thoughts about future research directions.

II. Data sources and issues

This work is restricted to the Summer and Winter Olympic Games from 1952 to the present, including predictions for the 2002 Winter Games. Work on earlier Games faces difficult data issues, primarily in economic data definitions, but this dataset permits interesting comparisons across 26 international celebrations of athletics (13 in each season), comprised of 3190 events, over 9200 awarded medals, and over 100000 athletes (of whom roughly 25000 were women).

Significant political boycotts occurred in three recent Games: 1976 (many African nations), 1980 (many Western nations) and 1984 (Eastern and Central Europe with the Soviet Union). Our analysis does not include participation data for nations which for political reasons chose not to participate in a given year. Likewise, data are omitted for nations that were not fully independent at the time of a Games (e.g. Guam) or were precluded from competition (e.g. South Africa or Libya for several Games).

Olympic information is from official sources (International Olympic Committee, various years) supplemented by a secondary source using the same original material (Wallechinsky, 2000 and 2001). GDP per capita data are in constant 1996 international prices for all years, to control for differences in international purchasing power (Heston et al., 2001). Population and expenditure data are from the same source, supplemented by the Statesman's Yearbook (which also provided all political variables).

Latitude and frost data come from the agricultural economics literature (Masters and McMillan, 2001), while urbanization data are found in the World Bank's Global Development Network Growth Database (Easterly and Sewadeh, 2001). Obvious gaps were filled by interpolation between surrounding year values, and extrapolations were made to permit out-of-sample predictions for the 2002 Games. While this adds an extra degree of error into the predictions, it provides an interesting test for the precision of our coefficient estimates.

We chose not to include lagged performance variables (i.e., past Olympic participation or medal success) in any of our analyses. Although lagged performance variables are highly effective explanations and predictors (Bernard and Busse, 2000), our interest is in the effect of purely economic and political variables. Under our interpretation, if unraveled, past medal counts would be explained by previous GDP per capita and previous medal counts, which would in turn be explained by previous variables devolving down to GDP per capita several periods ago.

Global participation in the Olympic Games is actually a very recent phenomenon, and still does not extend to the Winter Games. While the geographic diversity of participants has increased dramatically since 1952, the concentration of athletes from high-income developed nations has been increasing over time as well. In 1952, one in five participants at the Summer Games (one in twelve for the Winter Games) represented nations in the top ten percent of a list of participant nations ranked by income per capita. In the most recent Summer Games, one in three (one in two for the Winter) , came from nations in the top ten percent of the list. While the pool of athletes has been widening, the concentration from high-income nations has been getting deeper.

The gender balance among athletes has been growing closer over time, with parallel progressions in both Summer and Winter Games. From a post-War high of over 8 male athletes for each female athlete, the ratio had improved by Nagano (Winter 1998) to roughly 1.5 male athletes per female athlete.

There have been an average of 9 to 13 competitors per medal at virtually every venue (Summer and Winter) since 1952. This is undoubtedly due to the successful planning of the International Olympic Committee, who decide upon the number of participants per nation in advance of each celebration. The only exceptions to that range--- in the 1956 Summer Games and the 1960 Winter Games, the ratio was less than 6.5--- were terrific years to be a competitor! Of course, the number of participants per event varies widely, even within the same celebration of the Games.

Medalwinning success is still very concentrated. Of the exhaustive list of 241 nations and territories that attended the 1996 Summer Games, less than half have *ever* won an Olympic medal in any event, Summer or Winter. All African nations combined share a little over two percent of all Summer medals ever bestowed, and no African nation has ever won a Winter medal.

Nation size obviously breeds success at the Olympic Games. Nations that won at least one Summer medal average five times the population (and over fifty percent higher GDP per capita) of non-medal nations. Those figures alone are enough to warrant the investigation of the following section.

III. Who Goes? Participation in the Winter and Summer Olympics

A. Participants

The Olympic spirit is one of international community, built via participation by many nations. Yet not all nations are similarly able to send athletes, a fact which the International Olympic Committee recognizes in setting participation quotas for each nation in advance of the Games. Information on the decision process is (understandably) confidential, but it is clear that larger, higher-income nations consistently send more athletes to the Games.

While we cannot hope to accurately model the allocation process, we can offer some insight into the factors that presumably contribute to the participation decision. For example, consider a simple linear function with potential determinants of participation:

$$part_i = \alpha + \beta_1 GDP + \beta_2 GDP^2 + \beta_3 POP + \beta_4 POP^2 + \beta_5 HOME + \beta_6 NEIGH$$

$$+ \sum_{j=7}^{10} \beta_j POL_j + \beta_{11} LFROST + \beta_{12} HFROST + \beta_{13} t + u_i + \varepsilon \qquad \textbf{(1)}$$

where $part_i$ is a measure of participation from nation i

GDP is GDP per capita of nation i in constant international prices (in thousands)

POP is the population of nation i (in millions)

HOME is a dummy variable to indicate the hosting nation

NEIGH is a dummy variable to indicate immediate geographical proximity to the hosting nation

POL_j is a series of dummy variables to indicate a monarchy, single-party, military or other political environment (compared to a republic or parliamentary democracy)

LFROST is the share of land area feeling a light frost (less than 5 days per winter month)

HFROST is the share of land area feeling a heavy frost (more than 20 days per winter month)

t is a time trend (1=1952 Games, 2=1956 Games, etc.)

and where u_i is a nation-specific error term and ε is the unexplained error. Notice that in all regressions, the variables for political systems classified as republics or parliamentary democracies are omitted to avoid collinearity (so political variables are expressed relative to that baseline).

We present OLS results using nation-fixed effects (which vary by Winter/Summer season as well), using actual participation numbers as the dependent variable. However, results from a Poisson maximum likelihood estimation (which treat participation data as countable arrivals or occurrences) are very similar in interpretation and significance. Results in Table 1 are presented for all athletes and for female athletes alone.

Other variables were originally included but revealed no change in the significance of the variables above, or were highly correlated with variables already included. Variables indicating the relative importance of government and consumer spending in GDP were found to offer no improvement on the existing explanation. A dummy variable for political systems permitting voting was highly correlated with other political variables, and offered a worse fit than the series of political variables chosen. Variables measuring the share of the population residing in rural areas, and average degrees of latitude from the equator were highly correlated with GDP per capita and frost variables respectively, and presented no change to the results.

Use of a log-linear functional form showed similar results. While it has the benefit of a parallel with Cobb-Douglas production functions (with GDP per capita as "capital" and population as "labor") it offered no better fit to the data and could be slightly misleading. The objective here is not to estimate a production function but to examine the structural correlates of participation.

Nations with higher incomes (GDP per capita) send more participants to both the Summer and Winter Games, although the summer effect is more linear and the winter effect is more pronounced. On average, nations send 4 or 5 more participants per thousand dollars of GDP per capita. Since the U.S. has a GDP per capita approximately 18 times that of Nigeria's $1000 level, this effect alone suggests that the U.S. will send 80 more athletes to any celebration.

For the Winter Games, the effect is only significant for squared GDP per capita, indicating that participation rises quadratically with income. Low income nations choose to send no athletes at all, and high income nations send large contingents, with a much larger gap between participation numbers than is true in the Summer Games, or is true of the income gap itself.

High income nations send more female athletes, at least to the Summer Games, and again the effect is quadratic with respect to income. An additional $1000 GDP per capita would raise the average nation's female participation by two athletes, and this impact alone infers that the U.S. will send 36 more female athletes to the Summer Games than Nigeria would. The impact of income on female participation in the Winter Games is insignificant, because the average athletic contingent from a high income nation (the only nations competing in the winter) already incorporates a higher percentage of women than their lower income counterparts do.

For the Summer Games, nations with larger populations unambiguously send more athletes, but there is no evidence of that relationship in the Winter Games. On average, nations send an extra athlete to the Summer Games for every additional 3 to 4 million citizens. The effect is similar, but one-seventh as large, for female athletes (taking an extra 25 million citizens to support an addition to the roster) and is entirely absent in the Winter Games. Removing extremely large nations from the sample does not appreciably affect any estimated coefficient except for that of squared population (making it positive but insignificant). Omitting China and India also somewhat artificially boosts the explanatory power of the regressions by truncating variation in the variables.

The "home nation" bias is the most significant effect listed, both statistically and in numerical importance. For Summer Games the home bias is overwhelming in size, with the home nation sending an average of 210 more athletes than it would given its other characteristics, 63 of whom are female. The home bias is similarly important, but less overpowering, in the Winter Games, where the host sends an additional 32 athletes of whom 7 are women. Since host nations are always among the most developed in the world, there is some correlation with income levels, and it is unclear that less developed nations would enjoy the same dramatic advantage if they were to host on a regular basis.

For the Summer Games only, neighboring nations send an average of 45 more participants than expected, of whom roughly one-third are female. Interestingly, the neighbor bias for Winter Games is nonexistent, perhaps because the range of historical venues is more limited geographically.

The importance of these home and neighbor effects cannot be overstated. Aside from the obvious impact on the competition in the Games and the role of the crowd, this bias offers a numerical advantage towards winning events, assuming that each participating athlete has some probability of winning.

Political systems have some small effect on participation levels, as compared with the omitted comparison case of republics and parliamentary democracies, but (again) exclusively for the Summer Games. While monarchies, military systems and "other political systems" (those in transition to democracies, those with ill-defined power structures) send fewer athletes than democracies do, there is no evidence that single-party and Communist nations send more or less than predicted by other variables. The same pattern holds true for both male and female athletes.

Finally, a cold climate appears to have a positive effect on participation for Games in both seasons. While any winter climate (light or heavy) encourages Summer participation, only heavy winter climates have a positive effect on Winter Games participation. These results are expected, as all temperate zones (having a winter of some degree) tend to have higher income levels, and participate more heavily in the Summer Games. A subset of those nations, those with significant winters to permit regular practice and the development of winter sports programs, participate most actively in the Winter Games.

B. Predictions for 2002 and the "cost" of participation

These coefficients match previous literature (Johnson and Ali, 2000) very closely, and since those results provided excellent out-of-sample predictions for the Sydney Summer Games of 2000 (correlation of 0.96 with actual participation numbers by nation), we feel confident enough to do so here for Salt Lake City in 2002 in Table 2. As additional evidence, in-sample predictions of participation by 79 nations in the 1998 Winter Games (all nations with complete data) have a correlation of 0.95 with actual participation values. For the table, in cases where national estimates were limited by data constraints, predictions were inferred by trend relative to other nations. Our estimate of global participation puts the 2002 Winter Games at just over 2300 athletes, up a full eleven percent from the previous celebration.

The most striking element of Table 2 is the low participation figure for the U.S.A., which strikes the authors as inappropriate (especially for the hosting nation). Otherwise, the list proceeds with few surprises, with Japan sliding down the list after hosting in 1998, and Canada rising somewhat.

Given our estimated coefficients, we can infer how much GDP per capita would have to rise in any nation to support an additional participant. In a sense, the required rise in total GDP can be construed as the "cost of an extra participant", although we must qualify that phrase immediately. A rise in GDP brings obvious benefits to citizens (since it represents the market value of goods and services produced) over and above any correlation with Olympic participation. An extra Olympic participant is more of a positive externality, or fringe benefit, associated with a rise in GDP. Values for top participant nations of interest are listed in the last column of Table 2.

Unfortunately, data availability limits comparison to a narrow range of nations. However, it is still apparent that the additional GDP required to send an extra participant is smaller for higher income nations, both in absolute size per capita and as a share of GDP. The U.S. requires the smallest increase, of $185 per capita or about 0.9 percent of an increase in GDP, whereas Poland requires an enormous increase of $751 per capita (17.4 percent of GDP). These figures again point to the quadratic effect of income levels on participation, emphasizing the enormous advantage held by high income nations in the Winter Games. In essence, there is a fixed cost to participation, and after that the marginal cost of an additional athlete is relatively low. However, until the national contingent is large, the fixed cost, which must be spread across all athletes, is somewhat prohibitive.

Out of interest, the nation holding the record for most participants per citizen was Seychelles, with a rate of over 193 athletes per million inhabitants (in the 1980 Summer Games they sent a delegation of 12 participants). The winter record is held by Iceland (1952 Winter Games) who sent 11 athletes for a rate of over 75 athletes per million citizens. The corresponding records for most female participants per citizen are held by the same nations (each with a pair of women athletes, Seychelles in 1980 and Iceland in 1976) at rates of 32 and 9 women athletes per inhabitant respectively.

If we consider records for the number of participants per dollar of GDP, the undisputed winner is Romania (0.31 and 0.05 athletes per thousand dollars of GDP at the 1964 Summer and 1968 Winter

Games respectively). For female participation, China leads all others (0.10 and 0.01 female athletes per thousand dollars of GDP at the 1988 Summer and 1984 Winter Games respectively).

IV. Who Wins? Medalwinning at the Winter and Summer Olympics

It is a great mark of national prestige to succeed in the medal counts at the Olympic Games, so it is important not only to consider participation, but medalwinning as a goal of analysis. We present three complementary methods here: success at the national level by counting medals won, success in the medal rankings by counting a nation's share of total medals bestowed, and the probability of success at the individual level. After all three approaches, a summary offers our predictions for the Salt Lake City Games of 2002, as well as our estimates of the "cost" of a medal for a list of nations.

A. Nations and medal counts

From a national perspective, winning a medal is a two-step process involving sending participants and then encouraging those athletes to excel. The Heckman two-step process would determine coefficient estimates that avoid sample selection bias due to nations that do not participate (and therefore cannot possibly win a medal). However, coefficient estimates are similar in magnitude and interpretation to simple panel OLS estimates with nation-fixed effects. Since we are primarily interested in the subset of nations that participate, and since panel OLS results offer somewhat more accurate in-sample predictions, we present only those estimates here, warning the reader that these coefficients apply only to participant nations.

As before, consider a simple linear function to assess the determinants of medal-winning or success:

$$medals_i = \alpha + \beta_1 GDP + \beta_2 GDP^2 + \beta_3 POP + \beta_4 POP^2 + \beta_5 HOME + \beta_6 NEIGH$$

$$+ \sum_{j=7}^{10} \beta_j POL_j + \beta_{11} LFROST + \beta_{12} HFROST + \beta_{13} t + \beta_{14} MED + u_i + \varepsilon \qquad \textbf{(2)}$$

where $medals_i$ is the number of medals earned by nation i, MED is the number of medals available to be awarded, and other variables are defined earlier. The first column of Table 3 presents results for all medals earned by a nation, while the second column presents estimates for gold medals alone.

In parallel to results for participation, per capita income has a positive impact on medal winnings, but since the range of income is limited among nations with participants in the Games, the coefficients are smaller in impact. Participant nations average one more medal per \$1000 GDP per capita in the Summer Games, but need over twice that much for an extra medal in the Winter Games. Furthermore, income seems to play no explanatory role in Winter gold medals, although there is a positive but decreasing impact of income on Summer gold medals.

More populous nations win more medals (and more gold medals) at the Summer Games at an average rate of one medal per ten million inhabitants (one gold medal per 30 million inhabitants). Interestingly, *less* populous nations fare slightly better in the Winter Games, although the edge is slight.

As in participation, the home nation has a strong advantage, taking home 25 more Summer medals (and 3 more Winter medals) than expected, including 12 Summer gold medals and 1 Winter gold. Neighboring nations share marginally in the bounty, earning 2 more Summer medals than anticipated, but no extra gold and no edge in the Winter at all.

There is insufficient data on participating monarchies or military regimes to offer conclusions about medal performance, but it is strikingly obvious that single party and Communist systems outperform expectations by an huge margin. They average 18 Summer medals (8 of them gold), and 10

Winter medals (5 of them gold) above their peers with the same economic and geographic attributes. It is a tribute to the athletic systems of these nations that these winnings come despite evidence that they send no more participants than expected, but rather simply excel once they have arrived.

Colder nations outperform their competitors by a large amount, in both Summer and Winter Games, a variable which captures the performances of Canada, Russia and Scandinavia especially. Finally, the time trend and count of available medals tend to counteract each other. While it has become more difficult to win any given medal over time, it becomes easier to win any medal as the number of available medals increases.

B. Nations and share of medals awarded

As a test of robustness, we report a second formulation. Since the number of medals a nation can win is limited by the number of medals available, it also makes sense to estimate medal winners as a share of the total (Bernard and Busse, 2000). The estimation equation here is identical to **(2)**, but is at the national level, and a limited dependent variable (ranging from zero to one). Results are presented in the third column of Table 3, and while some variables were dropped to avoid collinearity issues, the remaining results are very similar to those of other formulations. They differ primarily in the increased importance of climate, and insignificance placed on the single party/Communist system. In-sample predictions for the most recent celebrations in each season are adequate but not outstanding, holding a correlation with actual medal standings of 0.66 for the Summer Games and 0.58 for the Winter Games. As a result, we will not use these estimates for out-of-sample prediction.

C. Individuals and success

Finally, we approach the medal competition from the viewpoint of the individual athlete, where the probability of winning is affected by the national support offered to him or her. We use an ordered probit to model this process, with characteristics of each athlete's nation affecting the probability of achieving any medal, and subsequently affecting the probability of reaching higher medals. An ordered probit simply recognizes that each successive medal is more difficult to obtain, so that in order to win a silver medal the athlete must also have been able to win a bronze medal in that same event.

As in **(2)**, consider a simple linear function to assess the determinants of medal-winning or success, with the same variables defined earlier, here based on the participant's nationality. The dependent variable for each observation (i.e. athlete) is their performance level--- 3 for a gold medal, 2 for a silver medal, 1 for a bronze medal, and 0 for participating with no medal success.

The results for almost 90000 athletes over 26 Games are presented in the last column of Table 3. As they mirror closely the direction and significance of coefficients in the other analyses, we feel confident in our primary model (based on nation medal counts). Therefore, we omit discussion here and proceed to out-of-sample predictions.

D. Medal predictions for 2002 and the "cost" of winning

In-sample medal count predictions for the 1998 Winter Games have a correlation of 0.94 with actual medal counts (and 0.88 with gold medal counts). Comparable values for the most recent Summer Games are 0.95 for medals and 0.96 for gold medal counts alone. As a result, we feel quite confident in the overall predictive pattern of our estimates, although individual nation results naturally have a large degree of uncertainty. Medal predictions for the Salt Lake City Games of 2002 are presented in Table 4.

Once again, since data are not available for all nations, medal counts for nations marked with an asterisk were inferred as a share of the remaining medals to be won (based on their performance in previous celebrations). In addition to the limitations mentioned above to participation projections, there is a reliance here upon predictions of total medals to be awarded, in order to predict their distribution among nations. Since the precise number is unknown (due to ties in which several medals of one rank are presented, or occasional cancellations) the totals are based on an estimate of 235 awarded medals. Naturally, if there are a different number of medals awarded, estimates could be rescaled to mirror the true total.

The medal predictions have some anomalies hidden in a list that otherwise conforms well to historical precedent. For example, Germany still tops the list but has an almost unbelievable lead on the rest of the field. Were this to occur in Salt Lake City, it would certainly be known as the first German Winter Olympics held outside of Germany. Part of that lead has been caused by the slippage of Norway, which has been replaced by Russia in second place. The U.S., bolstered by the home field audience, ties for third with Norway. Other surprises include the huge gains by Switzerland, Sweden and two newcomers to the list--- Iceland and Luxembourg--- largely due to their combinations of cold climates, high income per capita and small populations.

These irregularities point out some limitations of the out-of-sample prediction method. Instead of reading these predictions as a gambling handbook to the Olympics, the careful reader should treat them as a guideline to how well nations would be expected to perform given their national economic and political attributes. Departures from the predictions may signify unavoidable fluctuations around the average relationships of the model, or may equally simply reflect underlying differences between nations across time not included in our variables. Finally, and in a most satisfying way, they may reflect personal characteristics of athletes, trainers, coaches and athletic infrastructure that remain the primary focus of the competitions.

We also present estimates of the "cost" of a medal, and a gold medal in particular, using the same methodology detailed in the participation section. Naturally, the same caveats and warnings about interpretation apply here. In fact, since coefficients have been estimated only for participant nations, and cannot be extended with confidence outside of that set, values in this table must be considered with even more care than for participation estimates.

On average, an additional medal is associated with an increase of roughly \$1750 income per capita, or growth of 11 percent for the nations listed in the Table. Naturally, the cost (and implicit growth required) is lower for high income nations, reaching a low of \$1645 per capita (8 percent growth) for the U.S. For gold medals, the values are naturally much higher, averaging almost \$4750 per capita (a 30 percent growth rate) for most nations. Notice especially that for Korea, an additional gold medal is associated with an astounding 67 percent increase in GDP per capita.

These values have another interpretation as well. If an athlete unexpectedly wins a medal, it is as if his or her nation has received the Olympic benefits associated with a rise in income. In a sense, an unexpected gold medal creates the Olympic sensation normally only associated with nations having incomes \$4750 higher per person. It is small wonder then that medallists are showered with gifts and congratulations, and that festivities treat the athlete as a hero in low income nations where the victories are more rare and the percentage impact on "Olympic income level" is much greater!

The "cost" of a medal also drives home the message that low income nations will never be able to win more Olympic success based on rapid growth rates. The required values are simply too high. They must rely on athletic ability, population, and the introduction of new events to swing the medal counts in their direction.

Some would argue that the most successful nation at each celebration of the Games is the nation with the most medals per citizen, or most medals per dollar of income per capita. Norway has seven of the top eight places on the list for most winter medals per citizen, setting the current record of over 6 medals per million inhabitants at home in 1994. They also hold the top six positions on the list of most gold medals per citizen, with a 1994 record of one for every 1.4 million citizens. The summer records are held by Iceland (1956, 6.3 medals per million citizens) and Luxembourg (1952, 3.4 gold medals per million citizens).

If "low cost" is the goal, the USSR set the standard in winning the most Winter medals per dollar of GDP per capita. In the 1964 Games they won 0.009 medals (and 0.004 gold medals) per dollar of income per capita, but fill five of the top six places in both lists with other similarly impressive numbers. China has been even more spectacular in the Summer Games, winning 0.04 medals (1992) and 0.02 gold medals (2000) per dollar of income per capita.

V. Which Event? Differences between athletic events

It is now obvious that there are differences between the Winter and Summer Olympics (e.g. income helps more in participation in the Winter, population in the Summer, and both are more instrumental in garnering Summer medals than Winter medals). This begs the obvious question of whether there are discernible differences between events as well, even within the same celebration. It seems natural that there would be an advantage to populous nations in events which rely on physical endurance or strength, primarily because they will have a larger population upon which to draw for participants. Similarly, there might be an advantage to high income nations in events which rely on equipment or expensive facilities.

To test for differences, we created six categories of events, three parallel categories in each season's celebration. Labor-intensive events in the Summer Games include wrestling, judo, the marathon and 10000 meter run, while labor-intensive events in the Winter Games are comprised of all cross-country/nordic skiing events. Capital-intensive Summer Games are those involving horses, the equestrian and modern pentathlon events, and sailing. The counterpart in the Winter Games consists of luge, bobsleigh and ski jumping, all of which require expensive dedicated infrastructure for practice. Finally, as a third type in each season, we propose team-based sports for the Summer Games of football/soccer, field hockey, softball, baseball, basketball, handball, volleyball and waterpolo. In the Winter Games, the group is very thin as the only team event consistently celebrated is ice hockey, although curling and speed skating relays will soon join that group.

While the results showed some statistically significant differences, the actual size of the differences was small. For example, in summer events, income per capita weighed most heavily in favor of competitors in capital-intensive events, but was insignificant in team events. Population size was significant and positive in all summer events, but with much larger relative impact in labor-intensive and particularly team events. In all winter categories, differences were tiny, perhaps due to the more limited number of events (and therefore medals to be won). Naturally, all of these results are sensitive to the particular events chosen as part of each group and other researchers may have more success with alternative groupings. Since the results add little to the overall conclusion of this paper, they are omitted here but are available from the authors.

VI. Conclusions

Regardless of the precise medal counts in this particular celebration of the Olympic Games, we can be confident of several facts. There is a significant and measurable participation advantage to larger, higher income nations, although income is more important in the winter and population is more important in the summer. Female participation is rising over time, augmented primarily by larger nations. Among participating nations, high income nations always perform very well in the medal counts, although the effects are more pronounced in the summer due to the difference in the participant pool. Interestingly, small nations outperform their larger competitors at the Winter Games, while the reverse is definitely true at the Summer Games.

Furthermore, there are undeniably large advantages to being the hosting nation, both in terms of participation and medal counts. Neighboring nations share in the advantages during the summer, but have no advantage in the winter. Single party and communist regimes do not send more athletes than expected, but once there, they excel at winning medals in either season. Finally, colder nations outperform warmer ones, even in the Summer Games.

Our predictions for Salt Lake City's Games of 2002 imply large athletic contingents from the U.S.A., Russia and Germany, with a surprising runaway win in medal counts for Germany (31 medals, 11 gold) while three nations (Russia, U.S.A. and Norway) battle for the next three positions at 20 or 21 medals apiece.

We provided estimates of the extra income per capita required to boost participation or medal counts for several prominent nations, finding that the cost of participation averages $260 per capita for major participating nations. The "cost" of a medal is $1700 per capita and rises rapidly to $4750 per capita for a gold medal.

Considering the public and professional interest that this work has generated, the authors are considering maintaining a website dedicated to ongoing analysis and predictions about the Games. This site will include historical data, comparisons to trend, and projections for nations of particular interest.

Finally, it is ultimately the hope of the authors that readers understand the spirit of this paper, as they share the Olympic spirit of international cooperation and athletic competition. The purpose of this paper, and of the Olympic movement, is not to point out winners and losers but to understand the processes by which we strive to excel.

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Table 1: National participation in all Games

Effects of economic and political variables on participation in the Winter and Summer Olympic Games, 1952-2000

Variable	**All Games**						**Separate Winter and Summer Games**					
	All participants			**Female participants**			**All participants**			**Female participants**		
	Coeff	**t-statistic**		**Coeff**	**t-statistic**		**Coeff**	**t-statistic**		**Coeff**	**t-statistic**	
Constant	-4.18	0.93		-3.68	2.74	***	-8.83	2.00	**	-8.23	5.59	***
Winter only							6.75	1.09		7.38	3.62	***
GDP per capita (thousands)	2.92	3.02	***	-0.14	0.37							
Winter only							0.11	0.09		-0.03	0.06	
Summer only							7.16	6.11	***	-0.24	0.53	
GDP per capita squared	0.15	3.30	***	0.14	6.90	***						
Winter only							0.13	2.17	**	0.04	1.56	
Summer only							0.10	1.77	*	0.21	8.77	***
Population (millions)	0.15	3.17	***	0.03	1.83	*						
Winter only							0.07	1.51		0.02	1.10	
Summer only							0.27	5.48	***	0.04	2.18	**
Population squared	1.2e-6	0.04		-2.4e-4	1.76	*						
Winter only							-4.1e-5	1.04		-1.0e-5	0.69	
Summer only							-3.4e-5	0.89		4.8e-5	2.92	***
Home nation	123.9	20.4	***	35.2	13.2	***						
Winter only							31.5	3.81	***	7.13	2.08	**
Summer only							209.8	26.7	***	62.7	18.8	***
Neighbor nation	22.2	6.99	***	6.86	4.99	***						
Winter only							3.25	0.78		0.18	0.10	
Summer only							45.4	10.6	***	14.2	8.04	***

(see next page)

Table 1 (cont.): National Participation in all Games

Variable	All Games						Separate Winter and Summer Games					
	All participants			Female participants			All participants			Female participants		
	Coeff	t-statistic		Coeff	t-statistic		Coeff	t-statistic		Coeff	t-statistic	
Political system												
Monarchy system	-37.8	2.29	**	-13.4	2.92	***						
Winter only							-12.7	0.83		-3.23	0.70	
Summer only							-60.9	4.00	***	-20.6	4.44	***
Single party or Communist system	5.40	0.35		1.23	0.28							
Winter only							1.06	0.07		1.20	0.27	
Summer only							9.90	0.69		0.31	0.07	
Military system	-18.1	1.14		-3.41	0.77							
Winter only							-11.3	0.78		-2.15	0.50	
Summer only							-25.6	1.76	*	-5.03	1.14	
Other system	-37.4	2.07	**	-12.7	2.53	**						
Winter only							-13.6	0.83		-3.36	0.67	
Summer only							-56.6	3.44	***	-19.6	3.90	***
Light Winter climate	24.4	2.66	***	5.80	2.24	**						
Winter only							5.25	0.63		1.57	0.61	
Summer only							40.4	4.80	***	9.69	3.72	***
Heavy Winter climate	42.5	3.48	***	6.44	1.86	*						
Winter only							33.4	3.03	***	4.96	1.44	
Summer only							53.2	4.82	***	10.39	3.00	***
Time trend	0.05	0.20		0.30	3.17	***						
Winter only							-0.12	0.38		0.01	0.09	
Summer only							0.16	0.50		0.89	6.94	***
Adjusted R^2		0.37			0.31			0.61			0.51	
No. of panel groups		276			273			276			273	
No. of observations		2478			1908			2478			1908	

Notes: Dependent variable = number of athletic participants from a nation in a specific year. Political system variable is measured compared to the omitted system, republics or parliamentary democracies. Significance indicated as * for 10 percent, ** for 5 percent, *** for 1 percent

Table 2: Participation in Salt Lake City 2002
out-of-sample predictions and "cost" of another athlete

Nation	2002 predicted athletes [rank]	1998 actual athletes [rank]	2002 predicted dollar "cost" per capita of additional athlete (and % GDP)
U.S.A.	177 [1]	192 [1]	185 (0.90)
Russia*	140 [2]	126 [4]	n/a
Germany	114 [3]	131 [3]	212 (1.20)
Canada	101 [4]	81 [10]	197 (1.03)
Sweden	94 [5]	104 [7]	219 (1.29)
Italy	90 [6]	119 [5]	246 (1.62)
Switzerland	87 [7]	74 [11]	190 (0.96)
Norway	84 [8]	83 [9]	240 (1.55)
Austria	82 [9]	104 [8]	246 (1.62)
France	77 [10]	112 [6]	228 (1.39)
Czech Republic*	73 [11]	66 [12]	n/a
Japan*	73 [11]	175 [2]	n/a
Kazakhstan*	71 [13]	64 [13]	n/a
Finland	71 [13]	27 [23]	247 (1.64)
Belarus*	69 [15]	62 [14]	n/a
P.R. of China*	67 [16]	60 [15]	n/a
Ukraine*	62 [17]	56 [16]	n/a
Great Britain	61 [18]	35 [20]	249 (1.67)
Slovakia*	44 [19]	40 [18]	n/a
Poland	43 [20]	41 [17]	751 (17.37)
All nations with data	1485	1332	268 (2.69)
All nations	2316	2077	n/a

Notes: Nations annotated with an asterisk were estimated based on trend instead of regression. See the text for details.

Table 3: Medal winning in all Games

Effects of economic and political variables on medal earnings in the Winter and Summer Olympic Games, 1952-2000

Variable	**OLS by participant nation, all medals**			**OLS by participant nation, gold medals**			**Probit by participant nation, share of all medals**			**Ordered probit by participant athlete, all medals**		
	Coeff	**t-statistic**		**Coeff**	**t-statistic**		**Coeff**	**t-statistic**		**Coeff**	**t-statistic**	
Constant	-5.70	2.10	**	-3.05	2.37	**	-2.07	7.58	***	-----	------	
Winter only	-2.83	2.15	**	-0.92	1.64		-4.50	4.18	***	-1.06	5.16	***
GDP per capita (thousands)												
Winter only	0.44	2.30	**	0.10	1.28		0.39	2.35	**	0.08	4.94	***
Summer only	1.01	3.41	***	0.52	4.02	***	0.28	3.71	***	-----	-----	
GDP per capita squared												
Winter only	0.01	0.46		0.01	0.71		-2.7e-3	0.32		-2.3e-3	2.86	***
Summer only	-0.01	0.97		-0.01	2.27	**	-0.01	2.67	***	2.9e-4	3.77	***
Population (millions)												
Winter only	-4.1e-4	0.06		4.5e-3	1.61		-1.7e-3	0.35		-1.5e-3	4.86	***
Summer only	0.10	6.59	***	0.03	5.56	***	0.01	6.80	***	2.5e-3	21.2	***
Population squared												
Winter only	-7.9e-7	0.15		-5.9e-6	2.58	***	3.5e-6	0.99		7.6e-7	2.97	***
Summer only	-6.1e-5	5.24	***	-2.1e-5	4.31	***	-1.2e-5	4.93	***	-2.0e-6	20.5	***
Home nation												
Winter only	2.82	3.53	***	1.39	3.76	***	0.61	0.73		0.13	2.46	**
Summer only	24.9	15.0	***	11.9	15.8	***	-----	-----		0.10	4.54	***
Neighbor nation												
Winter only	-0.06	0.13		-0.08	0.39		0.15	0.49		0.05	1.11	
Summer only	2.37	2.52	**	0.39	0.91		0.51	1.11		-0.02	0.88	

(see next page)

Table 3 (cont.): Medal winning in all Games

Variable	**OLS, all medals**			**OLS, gold medals**			**Probit, medal share**			**Ordered probit**		
	Coeff	**t-statistic**		**Coeff**	**t-statistic**		**Coeff**	**t-statistic**		**Coeff**	**t-statistic**	
Political system												
Monarchy system												
Winter only	-----	-----		-----	-----		-----	-----		-----	-----	
Summer only	-4.82	1.09		-1.61	0.92		-----	-----		-----	-----	
Single party or Communist system												
Winter only	10.3	3.49	***	4.79	4.23	***	1.35	0.72		1.20	13.0	***
Summer only	17.87	4.27	***	7.71	4.62	***	0.54	0.52		0.35	10.1	***
Military system												
Winter only	-----	-----		-----	-----		-----	-----		-----	-----	
Summer only	-6.22	1.50		-1.91	1.18		0.85	2.54	**	-----	-----	
Other system												
Winter only	-0.46	0.14		-0.25	0.21		-0.13	0.10		-----	-----	
Summer only	-3.58	0.76		-0.95	0.52		-0.64	1.23		-----	-----	
Light Winter climate												
Winter only	-1.67	1.11		-0.43	0.73		3.25	3.82	***	0.94	4.91	***
Summer only	2.14	0.88		0.12	0.13		1.99	7.12	***	0.32	11.7	***
Heavy Winter climate												
Winter only	4.26	3.42	***	1.32	2.83	***	2.76	6.10	***	0.28	5.43	***
Summer only	12.46	3.92	***	4.52	3.65	***	1.37	3.06	***	0.26	12.2	***
Time trend												
Winter only	-0.71	5.30	***	-0.22	3.63	***	-----	-----		-----	-----	
Summer only	-0.56	1.83	*	-0.30	2.11	**	-----	-----		-----	-----	
Available medals												
Winter only	0.05	5.33	***	0.05	3.47	***	-0.15	2.64	**	-----	-----	
Summer only	0.01	1.34		0.02	1.66	*	-0.02	1.04		-----	-----	
Adjusted R^2		0.47			0.43			n/a			0.04	
No. of panel groups		197			197			197			-----	
No. of observations		1397			1397			1397			88386	

Notes: Dependent variable = number of athletic participants from a nation in a specific year. Political system variable is measured compared to the omitted system, republics or parliamentary democracies. Significance indicated as * for 10 percent, ** for 5 percent, *** for 1 percent

Table 4: Medal success in Salt Lake City 2002
out-of-sample predictions and "cost" of another medal

Nation	2002 predicted medals (and gold)	[rank]	1998 actual medals (and gold) [rank]	2002 predicted dollar "cost" per capita of additional medal (and % GDP)	2002 predicted dollar "cost" per capita of additional gold medal (and % GDP)
Germany	31 (11)	[1]	29 (12) [1]	1706 (9.64)	4578 (25.9)
Russia*	21 (10)	[2]	18 (9) [3]	n/a	n/a
U.S.A.	20 (7)	[3]	13 (6) [6]	1645 (8.05)	4288 (21.0)
Norway	20 (6)	[3]	25 (10) [2]	1759 (11.4)	4837 (31.2)
Austria	16 (4)	[5]	17 (3) [4]	1768 (11.7)	4881 (32.2)
Finland	14 (4)	[6]	12 (2) [7]	1770 (11.8)	4360 (22.1)
Netherlands*	13 (6)	[7]	11 (5) [8]	n/a	n/a
Switzerland	13 (4)	[7]	7 (2) [13]	1660 (8.42)	4894 (32.5)
Italy	11 (3)	[9]	10 (2) [9]	1768 (11.7)	4653 (27.3)
Canada	11 (3)	[9]	15 (6) [5]	1675 (8.79)	4882 (32.2)
Sweden	10 (3)	[11]	3 (0) [15]	1722 (10.1)	4429 (23.2)
P.R. of China*	9 (0)	[12]	8 (0) [11]	n/a	n/a
France	8 (2)	[13]	8 (2) [11]	1737 (10.6)	4729 (28.9)
Japan*	7 (6)	[14]	10 (5) [9]	n/a	n/a
South Korea	4 (2)	[15]	6 (3) [14]	1946 (22.5)	5858 (67.7)
Iceland	4 (1)	[15]	0 (0) [--]	1752 (11.1)	4912 (32.9)
Great Britain	4 (1)	[15]	1 (0) [19]	1774 (11.9)	4804 (30.5)
Czech Republic*	4 (1)	[15]	3 (1) [15]	n/a	n/a
Belgium	3 (1)	[19]	1 (0) [19]	1746 (10.9)	4771 (29.7)
Australia	3 (1)	[19]	1 (0) [19]	1731 (10.4)	4696 (28.2)
Luxembourg	3 (1)	[19]	0 (0) [--]	1668 (8.61)	4396 (22.7)
Denmark	3 (1)	[19]	1 (0) [19]	1736 (10.5)	4721 (28.9)
All nations with data	166 (57)		158 (49)	1739 (11.1)	4746 (30.4)
All participant nations	235 (79)		205 (69)	n/a	n/a

Notes: Nations annotated with an asterisk were estimated based on trend instead of regression. See the text for details. Rank is assigned based on total medal counts, so does not conform to the Olympic standard of listing all nations winning gold medals ahead of other nations with higher total medal counts.