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WHO WINS THE OLYMPIC GAMES: ECONOMIC DEVELOPMENT AND MEDAL TOTALS

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Who Wins the Olympic Games: Economic Development and Medal Totals
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ABSTRACT

This paper examines determinants of Olympic success at the country level. Does the U.S. win its fair share of Olympic medals? Why does China win 6% of the medals even though it has 1/5 of the world's population? We consider the role of population and economic development in determining medal totals from 1960-1996. We also provide out of sample predictions for the 2000 Olympics in Sydney.

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1 Introduction

Every four years it begins anew, the hand-wringing and finger-pointing over a poor showing at the Olympics. The only real uncertainty is which countries will feel the sharpest disappointment over their poor performances. After the Barcelona Olympics, a headline in the New York Times read "Despite its 108 medals, U.S. rates mixed success." In 1996, headlines in London trumpeted "Olympic shame over Britain's medal tally" and "Britain in danger of being left at the starting line,"[1] while in Mexico, Japan, Singapore, Colombia and Egypt, medal totals below expectations led to national self-examinations. After Sydney, in Canada the Globe and Mail bemoaned "Canada's Olympic fears come true: Despite a few bright spots, athletes not only won fewer medals, they performed below their own and nation's expectations."[2] In this paper, we ask the straightforward question of how many medals countries should be expected to win by considering what factors influence national Olympic success.[3]

One possible avenue of inquiry would be to assess sport by sport the athletic talent in each country and predict the likelihood of success in each event. We then could then generate a prediction for a national medal total by summing across sports. We suspect this is the method employed by most national Olympic committees when offering predictions about how many medals their countries will win. We follow a different path by generalizing from individual sports.[4] While this has the disadvantage of missing nation-specific expertise in a particular event, it has what we believe is the larger advantage of averaging over the random component inherent in individual competition, enabling us to make more accurate predictions of national medal totals.

[1] The first paragraph of the subsequent editorial in The Times of London began, "John Major wants a successful sporting nation, rightly believing that it reflects a healthy nation. He needs to direct urgent attention to the somnolent government administration if Great Britain is not to become an international laughing stock. The British Olympic Association (BOA) today holds its annual meeting with a debriefing from Craig Reedie, the chairman, on the Games in Atlanta, where Britain's tally of 15 medals was perceived at home as being unsatisfactory."

[2] Headlines in the U.S., Germany, New Zealand, India, and South Africa also worried about pooring showings in Sydney.

[3] We look only at performance in the summer Games. All references to the Olympics or Games refer to the summer Games.

[4] This is driven at least in part by our self-professed ignorance about the sports in question. See footnote 24 for evidence on this point.

Even the most ardent xenophobes would not suggest that a single country should win all the medals, or even all the gold medals, at a given Olympic Games. The real question is how many medals qualify as a successful performance by a national team. There have been several attempts to put national medal totals in some sort of perspective.[5] In 1996 after the Atlanta Games, Eurostat announced that the European Union had "won" the Olympic Games since the 15 member countries had both more medals and more medals per capita than the United States (08/15/1996 USA Today). The United Nations Population Information Network went a step further by declaring Tonga the winner of the Games with a medal to population ratio more than twice as high as the nearest competitor (9.4 medals per million inhabitants).[6]

Population should play a role in determining country medal totals. Larger countries have a deeper pool of talented athletes and thus a greater chance at fielding medal winners. We present and test a simple theory of medal success based on population coupled with assumptions about the distribution of Olympic calibre athletic talent. We consider both the probability that a country wins at least one medal as well as the share of total medals it wins.

Pure population levels are not sufficient to explain national totals. If they were, China, India, Indonesia, and Bangladesh with 43+ percent of the world's population would have won more than the 6+ percent of total medals in 1996 that they actually won. We recognize the importance of available resources in enabling gifted athletes to train for, attend, and succeed in the Games. To this end, we extend the population based model to include a measure of resources per person in the form of GDP per capita.

The addition of per capita GDP dramatically improves the ability of the model to fit the data. While China, India, Indonesia, and Bangladesh have a huge share of world population, together they account for under 5 percent of world GDP in 1996, roughly equal to their share of medals. The main results are quite sharp. Over time, a country's real GDP remains the single best predictor of Olympic performance. Population and per capita GDP contribute equally at the margin implying that two countries with identical levels of GDP but different populations and per capita GDP levels will win

[5] While there is nothing in the recent academic literature on national Olympic performance, it was an active area of research in the early 1970's. See Ball (1972), Levine (1974), and Grimes, Kelly, and Rubin (1974).

[6] See http://www.undp.org/popin/popis/journals/poptoday/today0996.html or http://footwork.com/globe1.html for details.

the same number of medals.

While GDP is most of the story, it is not the whole story. Host countries typically win an additional 1.8 percent of the medals beyond what would be predicted by their GDP alone. The forced mobilization of resources by governments clearly can also play a role in medal totals. On average, the Soviet Union and Eastern Bloc countries won a share of medals higher by 3+ percentage points than predicted by their GDP.[7]

The rest of the paper is organized as follows. Section 2 describes the data employed in the empirical analysis. Section 3 presents a population-based model of Olympic success. Section 4 presents a national production function for Olympic medals. Section 5 predicts medal-winning in the Sydney 2000 Olympics, and Section 6 concludes.

2 Data

The data for this project consist of two main components: Olympic medal counts and socio-economic indicators. We obtained the medal data from Wallechinsky (1992) and direct correspondence with the International Olympic Committee (IOC). For our socio-economic indicators, we would ideally like to have a range of indicators including population, income per capita, income inequality and government spending. However, the difficulty of obtaining such measures for more than 150 countries over 30 years precludes us from considering anything but GDP and population. Our primary source for both these measures was the World Bank and the U.N. (see the Appendix for a more complete description).[8]

3 A simple theory of population and Olympic success

To organize our thinking about the sources of Olympic success, we start by considering the underlying distribution of athletic talent. As with most

[7]Shughart and Tollison (1993) argue that the change in the structure in economic incentives in the former Soviet countries is responsible for their lower medal totals in the 1992 Olympics.

[8]There are numerous judgement calls required in assembling real GDP data for countries in the former Soviet Union, China, and many protectorates.

physical attributes, athletic talent is most likely distributed normally in the world's population. If we think of countries as being arbitrary divisions of the world population, then we should expect to find medal-calibre athletes in proportion to the country's share of world population. If medals are proportional to athletic talent, then we would expect to find the following relationship in the distribution of Olympic medals. For country i

$$\text{medalshare}_i = \frac{\text{medals}_i}{\sum_j \text{medals}_j} = \frac{\text{olympic talent}_i}{\sum_j \text{olympic talent}_j} = \frac{\text{population}_i}{\text{world population}}. \quad (1)$$

Equation 1 will hold only if every country participates in the Olympics which is not generally the case. The actual relationship predicted by the talent distribution is therefore that the share of medals accruing to a country should be equal to its share of the total population of countries participating in the Olympics,

$$\text{medalshare}_i = \frac{\text{medals}_i}{\sum_j \text{medals}_j} = \frac{\text{population}_i}{\sum_j \text{population}_j} = \text{popshare}_i. \quad (2)$$

Equation 2 is easily tested empirically. Since there are many countries that win no medals at all, another relevant implication of Equation 2 is that the probability that a country wins at least one medal should be increasing in the country's population share.

There are several reasons related to the structure of the Olympics themselves to think that the linear relationship in Equation 2 will not hold in practice. First, countries cannot send athletes in proportion to their populations to compete in each event. This is most easily seen in the team competitions where each country has at most one entrant. Second, in medal counts, team events count as one medal even though a country must provide a number of athletes. This means that even if a country is able to send athletes in proportion to its size, it may still win a smaller share of medals than its size would predict. Finally, and perhaps most important for our analysis, the number of athletes that a country may send to the Olympics is determined by the IOC in negotiation with the country's Olympic committee. As a result, not all the Olympic calibre athletes from a large country are able to participate.[9] We allow for these nonlinearities in our empirical

[9] For example, qualifying to be a member of the US Olympic team in track and field is considered to be as difficult as winning a medal; former medalists regularly fail to qualify. In the 2000 Olympic trials two record-holders, Michael Johnson and Maurice Green, failed to qualify for the 200 meter dash.

	I	II
Population share	6.561 (2.247)	
Log population share		0.127 (0.009)
Log likelihood	-814.671	-707.037
Observations	1278	1278

Table 1: Probit of medal winning on population share

work by considering both the level of the population share and the log-level of population as determinants of medal shares.[10]

3.1 Results

This section empirically tests the talent hypothesis as specified in Equation 2. We begin with a probit model that tests the more general implication of Equation 2, namely that the probability of winning a medal should be increasing in population share. The results of this estimation, reported as marginal probability effects, are reported in Table 1. As predicted by the model, the probability that a country will win at least one medal is increasing in its population share. However, the fit of the model seems quite poor. Using a 0.5 cutoff probability, the model correctly predicts the medal status 65 percent of the time. However, almost all these correct predictions come from the pool of countries that do not win medals. The model predicts that only 6 percent of the countries would win medals instead of the actual 39 percent.[11]

As mentioned above, we have reason to believe that medal winning will not be directly proportional to population shares because of the structure of the Olympics themselves. The nature of the deviation from the simple theory is one-sided in that larger countries will win fewer medals than predicted by their population shares while smaller countries will win more. There are an infinite number of possible alternative specifications that we could implement to account for these deviations but for the sake of simplicity we will limit

[10]In a contemporaneous paper, Johnson and Ali (2000) investigate the economic and political determinants of participation at the games.

[11]Standard errors are reported in parentheses in all tables.

	I	II
Population share	0.590 (0.050)	
Log population share		0.015 (0.001)
Constant	-0.024 (0.002)	0.074 (0.005)
Log likelihood	463.919	581.047
Observations	1278	1278

Table 2: Tobit of medal share on population share

ourselves to log-levels.[12]

The results of estimating a probit in log-levels of population shares are given in Table 1. Again using 0.5 probability cutoff, the fit of the specification is now dramatically improved. Over 72 percent of the observations are predicted correctly, and the model predicts that 31 percent of the countries will win medals. Mispredictions are still more likely in the direction of missing an actual medal winner.

Next we turn to the medal shares themselves. Equation 2 predicts that medal shares will be increasing one-for-one in population shares. Results from a tobit regression estimating this specification are reported in Table 2. While population share is positive and significant, the estimated coefficient is significantly below one. The second column of Table 2 reports the same tobit in log levels of the population share. The fit is substantially improved with an increase in the log-likelihood. The coefficient estimate in the second column indicates that if average country were to double its population, it would win an additional 1.5% of the medals awarded.

Figure 1 gives a visual depiction of the fit of the estimation. The number of medals actually won by each country in 1996 is plotted along the horizontal axis, with the predicted values from the tobit specification in log levels of population share plotted on the vertical axis.[13] If the model fit the data perfectly, all observations would fall on the 45 degree line. The figure shows that the specification does particularly poorly in capturing the countries with

[12]This will apply for the rest of the paper as well.

[13]Figure 1 omits countries that did not win a medal in 1996 to make the image less cluttered.

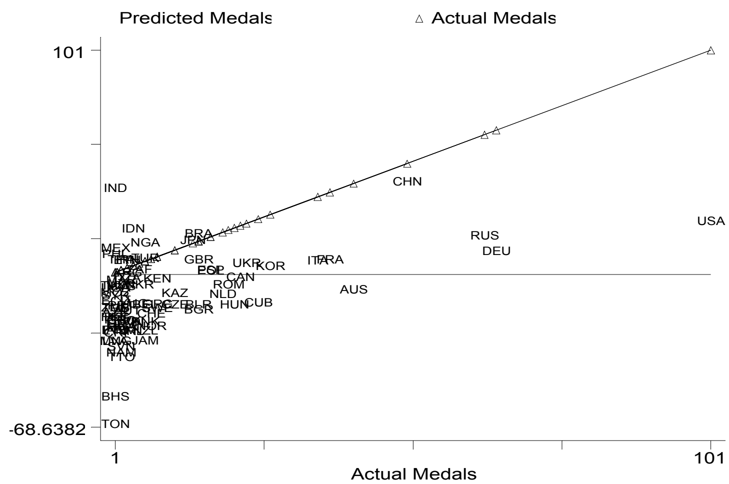

Figure 1: Predicted and actual medal totals for 1996 from the population tobit

the largest medal totals. The simple population model needs help to fit the data.

4 A production function for Olympic medals

To augment our model we now turn to the role of economic resources in generating Olympic medals. We choose to frame our analysis in terms of a production technology. In the previous section, we assumed that talented athletes were randomly distributed in the world population. However, there is a large and lengthy process involved in becoming an Olympic athlete and this process involves the allocation of resources, either by individuals or by an organization, most likely the central government.

Our production function for generating Olympic calibre athletes for a country i in year t requires people, money, and some organizational ability.[14]

$$T_i = f(N_i, Y_i, A_i) \tag{3}$$

[14] Time subscripts are suppressed for notational simplicity.

The share of Olympic medals, M_i, won by a country is a function of the talent in a given country.

$$\begin{aligned} \frac{\text{medals}_i}{\sum_j \text{medals}_j} &= M_i = g(T_i) \qquad \text{if } T_i \geq T^* \\ &= 0 \qquad\qquad\quad \text{if } T_i < T^* \end{aligned} \tag{4}$$

There is no theoretical guidance on the precise form of either $f(\cdot)$ or $g(\cdot)$. We choose a Cobb-Douglas production function in population and national income for the production of Olympic talent and a log function for the translation of relative talent to medal shares.

$$\begin{aligned} T_i &= A_i N_i^{\gamma} Y_i^{\theta} \\ M_i &= \ln \frac{T_i}{\sum_j T_j} \qquad \text{if } T_i \geq T^* \end{aligned} \tag{5}$$

This yields the following specification for medal shares,

$$\begin{aligned} M_{it} &= \ln A_{it} + \gamma \ln N_{it} + \theta \ln Y_{it} - \ln \sum_j T_{jt} \quad \text{if } T_{it} \geq T^* \\ &= 0 \qquad\qquad \text{if } T_{it} < T^* \end{aligned} \tag{6}$$

with the properties that increases in medals are less than one-for-one in both people and resources and there may exist country-specific organizational abilities that will increase or decrease the total medals won.[15] Since national income can be expressed as the product of population and per capita income, we will actually estimate a specification of the form

$$\begin{aligned} M_{it} &= C + \alpha \ln N_{it} + \beta \ln \left(\frac{Y}{N}\right)_{it} + d_t + \nu_i + \epsilon_{it} \quad \text{if } T_{it} \geq T^* \\ &= 0 \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad \text{if } T_{it} < T^* \end{aligned} \tag{7}$$

where d_t is year dummy included to capture changes in the total pool of talent and in the number of countries participating, as well as the changing number of sports, ν_i is a country random effect, and ϵ_{it} is a normally distributed error term.

[15] The term 'organizational' is merely a shorthand for all the possible reasons that countries may have high or low medal counts.

	I	II
Log population	0.016 (0.001)	0.014 (0.000)
Log GDP per capita	0.014 (0.001)	0.010 (0.001)
Random effects	No	Yes
Log likelihood	723.933	1075.051
Observations	1254	1254

Table 3: Tobit of medal share on population and per capita GDP

4.1 Results from the production function

As mentioned in Section 3, there are many participating countries who win no medals in a given Olympics. For this reason, we estimate Equation 7 with a tobit specification. Table 3 reports the results of this estimation. The dependent variable is the country medal share and all specifications include time dummies.

Both log population and log GDP per capita enter with positive and significant coefficients. The addition of a measure of national income dramatically improves the fit over the univariate specification with log population only, reported in Table 2. Interestingly, the coefficients on the two variables, although statistically distinguishable, are very similar, pointing toward log GDP itself as the relevant determinant of the share of medals a country wins. The second column of Table 3 reports the results including country random effects. We find again that the coefficients on the two explanatory variables are positive, significant, and of similar magnitude.

The coefficients estimated in this section can be loosely interpreted to mean that if the average country were to double its total GDP, it could expect the number of medals it wins to rise by 1-1.5% of the total awarded.

4.2 Additions to the model

The empirical specification given in Equation 7 shifts all country-specific information not included in GDP and population into the error term. In this section we explore some of the additional factors that might augment or diminish medal shares including the advantages of hosting, the medal premium enjoyed by the former Soviet Union and its satellites, and the role of large scale boycotts.

Hosts have several potential advantages over other Olympic participants. First, the cost of attending the Olympics for individual athletes is minimized. In addition, host countries can tailor facilities to meet the needs of their athletes and may gain an edge if home crowd enthusiasm sways judges.[16] Individual athletes may be more motivated to achieve Olympic fame when the events are conducted in front of friends and family. Finally, host countries are influential in the addition of new sports to the Games themselves. All these factors suggest that hosts should enjoy supranormal medal shares when the Games are in their country.

One of the most interesting questions regarding Olympic medal totals over the past 40 years concerns the ability of countries to 'manufacture' gold medals. Concern about this process stems from the apparent success of the former Soviet Union and Eastern European countries. These countries clearly accumulated large quantities of Olympic gold, silver, and bronze over the years. However, the unconditional medal totals cannot tell us how successful they were at mobilizing resources. We create two dummy variables to capture these effects. The first covers countries distinctly inside the Soviet sphere of influence while the second includes other non-market, typically communist, countries.[17] We consider the additional medals for these groups after controlling for income and population to provide a first estimate of the power of central planning in the Olympic race.[18]

Two Olympics in the era we examine were subject to large scale boycotts, those in 1980 and in 1984. Heretofore all our results have included those Olympics.[19] The coefficients on the host dummy and the dummies for the centrally planned economies are likely to be particularly sensitive to the inclusion of these Games and so we provide some evidence on the robustness of our results excluding the 1980 and 1984 Games.

[16] This was certainly the US perception of the results for selected boxing matches in the 1988 Olympics.

[17] The 'soviet' dummy includes Bulgaria, Czechoslovakia, Poland, the USSR, East Germany, Hungary, and Romania from 1960-1988, the Unified Team in 1992 and Cuba throughout the period. The other 'planned' dummy include China, Albania, Yugoslavia (through 1988), and North Korea.

[18] We should caution again that our GDP per capita numbers for these countries are far from perfect.

[19] All the results of the previous sections are robust to the omission of these boycotted Olympics.

The resulting specification is

$$M_{it} = C + \alpha \ln N_{it} + \beta \ln \left(\frac{Y}{N}\right)_{it} + \text{Host}_{it} + \text{Soviet}_{it} + \text{Planned}_{it} + d_t + \nu_i + \epsilon_{it} \quad (8)$$

Table 4 reports the tobit specification for medal shares with and without the boycotted years. The results for population and GDP per capita are largely unchanged; they are positive, significant and of the same magnitude as each other and are similar to those reported in Table 3. In two of the specifications, the coefficients on population and GDP per capita are statistically identical. The 'Soviet' countries do successfully increase their medal totals with shares more than 3 percentage points higher than other countries. Similarly, the group of other planned economies have shares that are higher by roughly 1.7 percentage points than those in the benchmark non-communist countries after controlling for income and population. Neither of these effects is sensitive to the exclusion of the boycotted Games.

The host effect on medal totals is also positive and significant. The bump in medal share from hosting a non-boycotted Olympics is almost 1.2 percentage points. During the boycotted Games the host effects were enormous, on the order of 19 percentage points, suggesting that the US and USSR were the prime beneficiaries from each other's boycotts in terms of medal counts.[20]

We finish by considering the adequacy of our sparse specification for the purposes of prediction. Given the lack of adequate summary statistics for the tobit, we instead present the results visually. Figure 2 shows the relationship between the predicted medal shares and actual medal shares for 1996 from our augmented tobit excluding the boycotted years (column II of Table 4). If the prediction were perfect all the country codes would line up on the 45 degree line. Predictions below (above) the 45 degree line are low (high) relative to the actual number of medals.[21] The model underpredicts medal shares at both the low and high ends of the range and overpredicts in the middle. While the additions of log GDP per capita and several dummies have improved the fit substantially, the overall predictive power of the current model is lacking.

[20] The US won 174 of 688 medals awarded in 1984, almost twice what it won in 1976 and 1988.

[21] Figure 2 omits countries that did not win a medal in 1996 to make the image less cluttered.

	I	II	III
Log population	0.0128 (.0007)	0.0127 (0.0007)	0.0083 (0.0004)
Log GDP per capita	0.0126 (0.0007)	0.0125 (0.0008)	0.0098 (0.0005)
1 if host country	0.0605 (0.0090)	0.0241 (0.0095)	0.0122 (0.0041)
1 if Soviet sphere of influence	0.0666 (0.0040)	0.0610 (0.0041)	0.0300 (0.0036)
1 if non-Soviet planned economy	0.0177 (0.0067)	0.0161 (0.0072)	0.0174 (0.0049)
Boycott years included	Yes	No	No
Random effects included	No	No	Yes
Log likelihood	862.064	738.227	984.044
Observations	1254	1036	1036

Table 4: Tobit of medal share on expanded explanatory set

4.3 Time to build

Until now we have implicitly modelled the production of Olympic athletes and medals as a within period flow process with potentially persistent country-specific organizational capabilities. However, it is quite likely that Olympic athletes are more similar to durable capital goods in that they may provide medal potential over several Olympics. This would suggest that investments for one Olympics may increase the chance of winning medals in subsequent Olympics.[22] To capture such effects we modify the medal production function given earlier to include slowly depreciating talent.

In particular, we assume that national Olympic calibre talent is a function of depreciated past talent and investment in new talent given by

$$T_{it} = (1-\delta)\,T_{it-1} + I_{it} \tag{9}$$

$$I_{it} = f\,(N_i, Y_i, A_i) = \ln A_{it} + \gamma \ln N_{it} + \theta \ln Y_{it} \tag{10}$$

[22]There is direct evidence on the persistence of success and failure in the games. The autocorrelation coefficient of the within-country errors from the earlier specification with random effects is as high as 0.45.

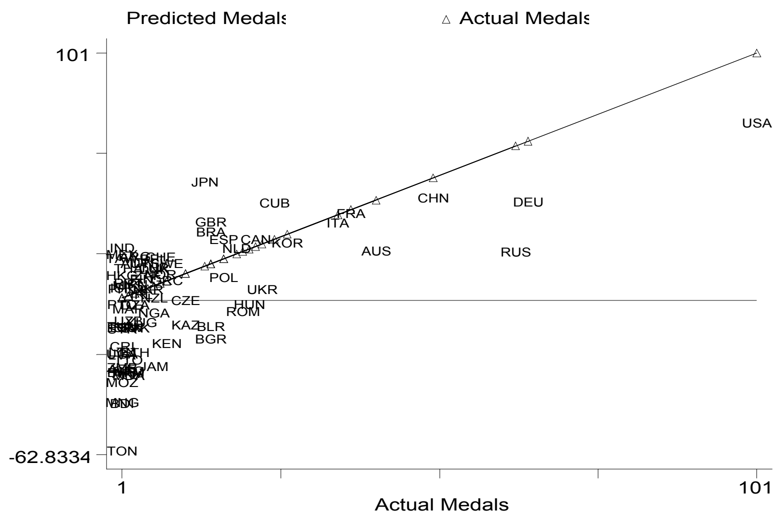

Figure 2: Predicted and actual medal totals for 1996 from the population and GDP tobit

Talent translates to medals proportionally,

$$\begin{aligned}\frac{\text{medals}_{it}}{\sum_j \text{medals}_{jt}} &= M_{it} = \frac{T_{it}}{\sum_j T_{jt}} \qquad \text{if } T_{it} \geq T^* \\ &= 0 \qquad\qquad \text{if } T_{it} < T^*\end{aligned} \tag{11}$$

After substituting, this yields the following specification for medal share:

$$\begin{aligned}M_{it} &= \frac{C}{\bar{T}_t} + (1-\delta)\,\frac{\bar{T}_{t-1}}{\bar{T}_t} M_{it-1} + \frac{\gamma}{\bar{T}_t}\ln N_{it} + \frac{\theta}{\bar{T}_t}\ln Y_{it} \quad \text{if } T_i \geq T^* \\ &= 0 \qquad\qquad\qquad\qquad\qquad\qquad\qquad \text{if } T_i < T^*\end{aligned} \tag{12}$$

where $\bar{T}_t = \sum_j T_{jt}$. Equation 12 implies that the coefficients on GDP per capita and population will vary negatively with the unobservable total pool of talent. The coefficient on lagged medal share will be constant over time if the pool of talent is increasing at a constant rate. For purposes of comparison, we first estimate the specification including lagged medal share with time-invariant parameters; in the next section we will allow the parameters to vary over time.

$$M_{it} = C + (1-\delta)\,M_{it-1} + \alpha \ln N_{it} + \beta \ln\left(\frac{Y}{N}\right)_{it} + \delta_t + \epsilon_{it} \quad \text{if } T_i \geq T^* \tag{13}$$

$$= \quad 0 \qquad\qquad \text{if } T_i < T^*$$

Results from this specification are given in Table 5. Because of the inclusion of the lagged dependent variable, we omit the boycotted games from the sample, and also the 1988 games since the 1984 medal shares are distorted by the Soviet-led boycott. The coefficients on population and per capita GDP remain significant and of equal magnitude to each other. Lagged medal share has a coefficient of 0.76 and is strongly significant.

Log population	0.0062 (.0005)
Log GDP per capita	0.0061 (0.0006)
Lagged medal share	0.7554 (0.0342)
1 if host country	0.0176 (0.0066)
1 if Soviet sphere of influence	0.0331 (0.0031)
1 if non-Soviet planned economy	0.0100 (0.0050)
Boycott years included	No
Random effects included	No
Log likelihood	798.485
Observations	885

Table 5: Tobit of medal share with lagged dependent variable

The estimated host effect is 1.8 percentage points while the Soviet effect and planned economy effect are 3.3 and 1.0 percentage points respectively.

4.4 Changes over time

Equation 12 suggests that we might find changes in the estimated parameters across years. If the overall pool of Olympic talent is increasing then we will see decreases in the coefficients on GDP per capita and population. Intuitively, as the world pool of talent grows, a country needs an ever larger GDP in order to win the same share of medal. As long as the rate of aggregate

		1964	1968	1972	1976
Log pop.		0.0043*	0.0032*	0.0034*	0.0016*
Log GDP percap		0.0036*	0.0029*	0.0032*	0.0038*
Soviet		0.0079	0.0202*	0.0229*	0.0191*
Planned		0.0084	0.0135	0.0052	0.0084
Lagged medal share		0.8585*	0.8720*	0.7789*	1.0314*
	1980	**1984**	**1988**	**1992**	**1996**
Log pop.	0.0012*	0.0199*	0.0077*	0.0060*	0.0018*
Log GDP percap	0.0007	0.0191*	0.0075*	0.0061*	0.0016*
Soviet	0.0005	0.0935*	0.0687*	0.0874*	-0.0001
Planned	0.0031	0.0174	0.0155	0.0178	-0.0016
Lagged medal share	1.4644*	-0.2613	0.3550*	0.8145*	0.8435*

Table 6: Year by year tobit of medal share on expanded explanatory set

talent increase has been roughly constant over time, the coefficient on lagged medal share will not vary across the years, as can be seen in Equation 12.

In Table 6, we report the coefficients on the specification run year-by-year without the host dummy (which would perfectly fit the medal share for the host). The results provide broad confirmation of the simple accumulation model we offered above. The equality of the coefficients on log population and log GDP per capita is stable over time. However, the marginal effects of both variables has been systematically declining over time. The coefficients on both variables are less than half their 1964 values by 1996. Lagged medal share is positive and significant in all the non-boycott years with a stable coefficient around 0.8. In addition, the year-by-year estimates suggest that the influence of the former Soviet Union and Eastern Europe is on the wane in recent years.

Including lagged medal share and estimating year by year tobits improves the fit of the specification substantially compared to the estimates reported in section 4.2, especially for countries with large medal totals. Figure 3 shows predicted and actual medals for 1996 from a tobit specification with lagged medal shares estimated on the post-boycott Olympics.[23] The model does

[23] Figure 3 omits countries that did not win a medal in 1996 to make the image less cluttered.

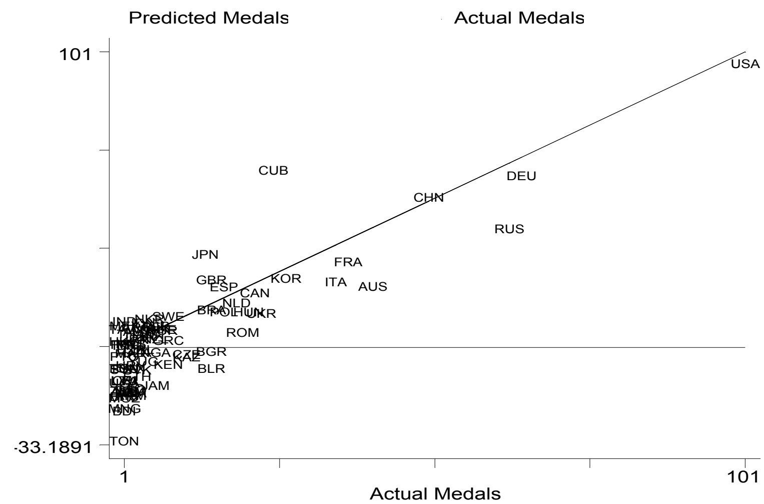

Figure 3: Predicted and actual medal totals for 1996 from the enhanced tobit

quite well in predicting totals for a number of countries including the USA, Germany, and China. However, Russia wins more medals than predicted while Cuba wins far fewer than predicted. Table 7 has a list of medals won by country and the predictions from the model for that year.

To sum up, the production function approach adds considerably to the simple talent hypothesis of Section 3. The statistical significance of GDP per capita indicates, perhaps not surprisingly, that economic resources are important in producing Olympic medalists. More surprising is the persistent similarity of the coefficients on log population and log GDP per capita. This suggests that it is a country's total GDP that matters in producing Olympic athletes. This has the implication that two countries with the same GDP will win approximately the same number of medals, even if one is relatively populous with lower per capita income and the other is smaller with higher per capita GDP. Furthermore, this section has identified some important country characteristics that boost medal totals, including Soviet and host effects. Finally, there is strong evidence for durability to a country's Olympic "investments". Past success is an indicator of current success; including lagged medal share further improves the fit of the model.

5 Predicting Medals in Sydney

To provide a sterner test of our framework, we evaluate its out of sample performance. To this end, we made public predictions based on the model several weeks before the 2000 Sydney games.4 To do so, we extended our data as best we could using recent data on population and GDP growth for a subset of countries. The most recent, most complete data we had available were from the IMF for 1998 population and GDP. Among the various specifications, we estimated the 1996 cross-section estimation from Table 6 including lagged medal shares. This specification does not estimate a host effect, so we use the coefficient on the host dummy for the same specification pooled over all non-boycott years (Table 5). We predict the total medal counts for the 36 countries that won at least five medals in 1996.

Table 8 contains two sets of predictions for the Sydney Games as well as the actual medal totals for the 36 countries. Columns 1 and 2 represent the predictions and standard errors the model would have made if it had been implemented without error. Column 3 gives the ex-ante predictions made public before the Sydney games, while column 4 gives the ex-post medal totals.[24]

Both sets of predictions, error-free and error-laden, do quite well in matching the outcomes from the games. While the error-free predictions hit only one total exactly, 9 countries are within one medal of their actual total, and 23 are within 3 medals. Using more formal distance metrics to measure our forecast performance, the predictions have an R^2 of 0.96 and 35 of the 36 countries were within 2 standard errors of the predicted values. The mean absolute error is 4.3 medals.

6 Conclusions

In this paper, we examine the question of how many Olympic medals a country should win. We begin with a simple hypothesis that athletic talent is

[24]The three mistakes we made in implementing the model were, in order of importance: (1) using an incorrect total of 888 medals instead of the actual 929, (2) forgetting to include year dummies in the pooled tobit which gives us the host effect, and (3) estimating the coefficients with zeros for lagged medal share for both the Czech Republic and Slovakia. The first mistake resulted from our deep ignorance about individual sports as we were not aware that the sports of boxing and judo awarded double bronzes. Our perfect, ex-ante predictions for the U.S. and France do not survive the corrections.

randomly distributed and that therefore medal winning should be proportional to population. We also consider a production function for Olympic medals that encompasses resources, population and other national characteristics.

While the simple population hypothesis does have explanatory power, it fails to adequately explain the distribution of medals across countries. We find significant evidence that other resources, national income in particular, are important for producing Olympic athletes. Interestingly, per capita income and population have very similar effects at the margin suggesting that total GDP is the best predictor of national Olympic performance.

While GDP is most of the story, it is not the whole story. Host countries typically win an additional 1.8 percent of the medals beyond what would be predicted by their GDP alone. This host bounce led us to predict that Australia would win 17 more medals in 2000 than it would have otherwise, making our medal prediction only one short of the actual total. The forced mobilization of resources by governments clearly can also play a role in medal totals. On average, the Soviet Union and Eastern Bloc countries won a share of medals higher by 3+ percentage points than predicted by their GDP and past performance during the 1960-1996 period.

We finish by exposing our simple specification to an out of sample test and predict medal totals for the 2000 summer games in Sydney. The model does quite well by most statistical metrics.

7 Appendix

Our primary source for population and GDP data was the World Bank. We also used United Nations data sources, and for a few observations, the CIA Factbook, The Economist magazine, and the Taiwan Statistical Planning Book. Population figures could be found fairly readily; GDP measures were more difficult. For some countries, especially less developed countries, it was necessary to interpolate or extrapolate using either reported or imputed growth rates. Also, there is an ever-present concern about GDP figures from the Soviet Union and its satellites, China, and protectorates. We do our best to compile comparable and reasonable data. All GDP figures are converted to 1995 US dollars using current exchange rates.

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Country	Actual	Pred.	Country	Actual	Pred.	Country	Actual	Pred.
United States	101	101	Puerto Rico	1	0	Guyana	0	0
Germany	65	77	Azerbaijan	1	0	Cayman Islands	0	0
Russian Federation	63	59	Mongolia	1	0	Paraguay	0	0
China	50	50	Uganda	1	0	Panama	0	0
Australia	41	26	Philippines	1	1	Sierra Leone	0	0
France	37	30	Mozambique	1	0	Niger	0	0
Italy	35	20	Hong Kong	1	1	Mauritius	0	0
South Korea	27	28	Lithuania	1	0	Tanzania	0	0
Cuba	25	25	India	1	3	Kuwait	0	0
Ukraine	23	20	Zambia	1	0	Nepal	0	0
Canada	22	19	Tunisia	1	0	Peru	0	1
Hungary	21	25	Burundi	1	0	Guatemala	0	0
Romania	20	15	Latvia	1	0	Vietnam	0	0
Netherlands	19	15	Syrian Arab Rep	1	0	Botswana	0	0
Spain	17	22	Israel	1	2	Liechtenstein	0	0
Poland	17	18	Cameroon	0	0	Cyprus	0	0
Brazil	15	6	Barbados	0	0	Comoros	0	0
United Kingdom	15	21	Turkmenistan	0	0	Vanuatu	0	0
Belarus	15	0	Iceland	0	0	Sudan	0	0
Bulgaria	15	11	Zimbabwe	0	0	Ghana	0	0
Japan	14	25	Grenada	0	0	Singapore	0	0
Czech Rep.	11	0	Congo, Dem. Rep.	0	0	Maldives	0	0
Kazakhstan	11	4	Bermuda	0	0	Equatorial Guinea	0	0
Sweden	8	12	Egypt, Arab Rep.	0	0	St. Lucia	0	0
Greece	8	2	Colombia	0	1	Belize	0	0
Kenya	8	4	Bangladesh	0	0	Liberia	0	0
Switzerland	7	3	Swaziland	0	0	Cape Verde	0	0
Norway	7	7	El Salvador	0	0	British Virgin Islands	0	0
Belgium	6	4	Pakistan	0	1	Malta	0	0
Turkey	6	7	St. Vincent	0	0	UAE	0	0
Denmark	6	6	Chile	0	0	Aruba	0	0
Jamaica	6	0	Fiji	0	0	Chad	0	0
Nigeria	6	3	Uruguay	0	0	Angola	0	0
New Zealand	6	8	Burkina Faso	0	0	Suriname	0	0
North Korea	5	5	Cambodia	0	0	Mali	0	0
South Africa	5	3	Jordan	0	0	Libya	0	0
Indonesia	4	6	Benin	0	0	Afghanistan	0	0
Yugoslavia	4	1	Nicaragua	0	0	Cote d'Ivoire	0	0
Ireland	4	1	Brunei	0	0	Yemen, Rep.	0	0
Finland	4	5	Albania	0	0	Lesotho	0	0
Iran, Islamic Rep.	3	3	Rwanda	0	0	Dominican Rep.	0	0
Argentina	3	3	Saudi Arabia	0	1	Lao PDR	0	0
Slovak Republic	3	0	Togo	0	0	Haiti	0	0
Algeria	3	1	Malawi	0	0	Luxembourg	0	0
Austria	3	3	Oman	0	0	Guinea-Bissau	0	0
Ethiopia	3	0	Central African Rep.	0	0	Bosnia	0	0
Malaysia	2	1	Macedonia	0	0	Bhutan	0	0
Georgia	2	0	Samoa	0	0	Tajikistan	0	0
Armenia	2	0	Sao Tome Principe	0	0	San Marino	0	0
Portugal	2	0	Cook Islands	0	0	Congo, Rep.	0	0
Moldova	2	0	Guam	0	0	Gabon	0	0
Uzbekistan	2	7	Estonia	0	0	Gambia, The	0	0
Morocco	2	2	Honduras	0	0	Solomon Islands	0	0
Namibia	2	0	Papua New Guinea	0	0	Venezuela	0	0
Thailand	2	2	Qatar	0	0	Mauritania	0	0
Trinidad Tobago	2	0	Antigua Barbuda	0	0	Myanmar	0	0
Slovenia	2	0	Iraq	0	0	Bahrain	0	0
Croatia	2	1	Somalia	0	0	Senegal	0	0
Ecuador	1	0	Guinea	0	0	Bolivia	0	0
Taiwan	1	3	Djibouti	0	0	Madagascar	0	0
Costa Rica	1	0	Sri Lanka	0	0	Dominica	0	0
Bahamas	1	0	St. Kitts and Nevis	0	0	Monaco	0	0
Tonga	1	0	Netherlands Antilles	0	0	Lebanon	0	0
Mexico	1	3	Kyrgyz Republic	0	0	Seychelles	0	0

Table 7: Actual and predicted medal totals for 1996

	Predicted 2000 medals (1)	S.E.E.	Predicted 2000 medals (2)	Actual 2000 medals
Australia	40 (57*)	(5.1)	39 (52*)	58
Belarus	12	(5.0)	12	17
Belgium	7	(5.1)	7	5
Brazil	18	(5.1)	17	12
Bulgaria	11	(5.1)	10	13
Canada	24	(5.1)	23	14
China	51	(6.2)	49	59
Cuba	21	(7.1)	20	29
Czech Republic	10	(5.0)	9	8
Denmark	7	(5.1)	7	6
France	39	(5.1)	38	38
Germany	66	(5.5)	63	57
Greece	8	(5.1)	8	13
Hungary	19	(5.1)	18	17
Italy	37	(5.1)	35	34
Jamaica	1	(5.1)	1	7
Japan	20	(5.2)	19	18
Kazakhstan	9	(5.0)	8	7
Kenya	5	(5.1)	5	7
Netherlands	20	(5.1)	19	23
New Zealand	5	(5.1)	5	4
Nigeria	5	(5.1)	5	3
North Korea	3	(6.2)	3	4
Norway	7	(5.1)	7	10
Poland	17	(5.0)	16	14
Romania	18	(5.1)	17	26
Russia	62	(5.4)	59	88
South Africa	6	(5.1)	6	5
South Korea	28	(5.1)	27	28
Spain	19	(5.1)	18	11
Sweden	9	(5.1)	9	12
Switzerland	8	(5.1)	8	9
Turkey	7	(5.1)	7	4
UK	18	(5.1)	18	28
Ukraine	22	(5.9)	21	23
US	102	(5.1)	97	97

Table 8: Total medal predictions for Sydney