

Modelling Olympic performance

Economic briefing paper



108

US

98

China

52

Great Britain

25

Brazil

Estimate of medal
total at the 2016
Rio Olympic Games

Executive summary

As we get closer to the start of the 2016 Olympic Games in Rio, so interest is rising in the likely medal tallies of different countries. As a contribution to this debate, this paper presents analysis on the determinants of past Olympic Games performance and uses this to produce some benchmarks against which performance at the 2016 Olympics Games can be judged. This updates similar analysis we produced around the time of the 2000, 2004, 2008 and 2012 Olympic Games.

The following factors were found to be statistically significant in explaining the number of medals won by each country at past Olympic Games:

- size of economies (measured by GDP at purchasing power parity (PPP) exchange rates);
- performance in the previous two Olympic Games; and
- whether the country is the host nation.

In general, the number of medals won increases with the population and economic wealth of the country, but there are exceptions like Jamaica or Kenya: David can sometimes beat Goliath in the Olympic arena, although superpowers like the US, China and Russia continue to dominate at the top of the medal table.

Past Olympic performance is important, reflecting the stronger sporting traditions in some countries, including those in the former Soviet bloc. We can see a similar effect at work in China more recently, where state support contributed greatly to their Olympic success in Beijing and London: sport it seems is one area where a planned economy can succeed!

Now it is no longer the host country, Great Britain may find it difficult to emulate its exceptional performance in London 2012, though our model suggests that it should remain high up the medal table. We find that host nations generally 'punch above their weight' at the Olympics, which bodes well for the Brazilian team in Rio, despite the recent economic problems in that country.

Overall, our model suggests that the USA could lead the way in Rio with a projected total of 108 medals (up slightly from 103 in London), followed by China (98), Russia (70)¹ and Great Britain (52). Team GB would be down on its London total, but still ahead of old rivals Germany (40) and Australia (35) according to the model projections. But all models are subject to margins of error and they can never take full account of the human factor of exceptional individual performances - so we will be only too pleased if the British team can beat our model projection in Rio this summer!

¹ This is contingent on Russian track and field athletes being allowed to compete in Rio, which is unclear at the time of writing given their suspension last year for serious anti-doping offences. An IAAF decision on this is due on 17th June, after this paper went to print. If these Russian athletes were not able to compete, this would have a material impact on the medal totals of other countries and we may issue an updated set of projections in that case.

Economic briefing paper: modelling Olympic performance

With the 2016 Olympic Games in Rio de Janeiro ('Rio') fast approaching, there will inevitably be much speculation about how many medals each country will win. In this paper we consider, as a light-hearted (but nonetheless reasonably rigorous) contribution to the debate, how far statistical models can help to explain the number of medals won by each country in past Olympics. We published the results of a similar modelling exercise around the time of the London 2012, Beijing 2008, Athens 2004 and Sydney 2000 Olympics and have now updated this analysis, taking into account also the results of other past studies in this area².

Key features of our model

The updated version of our model includes data on medal performance from the Olympic Games since 2000³. We find that, in explaining the share of the total medals awarded to each country, the following factors are statistically significant (see Annex for further technical details):

- size of economies (as measured by GDP at PPP exchange rates);
- performance in the previous two Olympic Games; and
- whether the country is the host nation.

David vs Goliath

In past versions of this paper we looked at both population and average income levels, but the coefficients on these variables were similar. It therefore seems to be total GDP that matters most in explaining Olympic performance rather than how this splits down between population size and average income levels.

But there are some countries whose Olympic performance is significantly out of line with that implied by GDP levels. Jamaica, for example, is projected to win 0.4 medals in Rio for every \$bn of GDP, while the same ratio is only around 0.02 for the UK and Russia, and around 0.005-0.006 for the US and China. There are a number of possible reasons for these disparities:

² In particular, A.B. Bernard and M.R. Busse, 'Who Wins the Olympic Games: Economic Resources and Medal Totals', *Review of Economics and Statistics*, 2002; and D.K.N. Johnson and A. Ali, 'A Tale of Two Seasons: Participation and Medal Counts at the Summer and Winter Olympic Games', Wellesley College Working Paper 2002-02, January 2002.

³ In earlier versions of this paper we looked back to 1988, but on reviewing the data we felt that the most information was contained in the more recent Games since 2000 when it came to making medal projections for 2016. We have therefore focused on these last four Olympic Games in our statistical analysis. Our results are, however, broadly comparable to those of the studies quoted in the previous footnote, which do cover a longer time span.

- as discussed in past versions of this paper, there is statistical evidence that the former Soviet bloc countries (including Cuba) significantly outperformed expectations based on their relatively low GDP levels, although this effect has faded over time and no longer shows up as statistically significant in our model if we also include past Olympic performance;
- outstanding athletes from smaller countries may be able to train in wealthier countries (e.g. by attending US universities) but may continue to represent their own countries in the Olympics; for a small country, one or two gold medal performances from such athletes can make a large percentage difference to their overall points scores;
- while outstanding athletes in large countries like the US may be spread across a very wide range of Olympic and non-Olympic sports, there may be more of a tendency for athletes in smaller countries to specialise in a narrower range of disciplines where there is a local track record of success (e.g. long distance running for Kenya and Ethiopia, or sprinting for Jamaica); this strategy of specialisation can prove proportionately very successful in producing Olympic medals (and is perhaps analogous to the development of specialised industry 'clusters' in particular countries/regions, where a virtuous circle can then develop to generate world class performance⁴); and
- although this is difficult to prove, it could be that there is more focus on sport in some poorer countries where other life opportunities are more limited; if true, this greater motivation to participate and excel in sport may make up to some degree for inferior training facilities, at least in the early stages of a career.

Whatever the explanation, the bottom line is that size matters, but it is not everything. David can sometimes slay Goliath in the Olympic arena.

History matters

We found that the explanatory power⁵ of the model was increased significantly by including medal shares at the previous two Games, which can be interpreted as reflecting the fact that sources of comparative advantage in sport tend to persist over time. Once this past performance is allowed for some other factors (particularly the ex-Soviet bloc effect as discussed above) are no longer statistically significant as they are already captured in past performance.

Home country advantage: good news for Brazil in Rio?

We also found the home country effect to be significant. In practice, however, this effect will vary across countries depending on their size and the strength of their sporting traditions. It was particularly strong for China in Beijing (where its medal total rose to 100 from 63 in Athens) and Great Britain in London (65 medals up from 47 in Beijing) and was also evident in the Sydney 2000 Olympics, where Australia performed very well to win 58 medals (compared to 49 in Athens and 46 in Beijing as this effect faded). But it was somewhat less evident in Athens,

⁴ This cluster theory was first developed in detail by Michael Porter in his book, *Competitive Advantage of Nations* (1990). Perhaps he could include a review of sporting excellence clusters in the next edition?

⁵ The explanatory power of our preferred model is high, as indicated by an adjusted R-squared of 0.97 (i.e. the model explains around 97% of the variance in medal shares between countries). If we exclude the lagged dependent variables, the explanatory power of the model drops to only around 50%.

where Greece only increased its medal total to 16, as compared to 13 in Sydney (and then fell back to just 4 medals in Beijing and 2 in London).

Overall, our model estimates suggest that home country advantage should on average boost Brazil from 17 medals in 2012 to around 25 medals in Rio in 2016, after allowing for other factors, including its current weak economy.

Other factors not captured by our model

Technical details of the model are discussed further in the Annex. It is not surprising that the model cannot explain all the variation in medal shares across countries as this will also be influenced by individual athletic performances, as well as by policy-related factors such as:

- **the relative level of state and corporate funding** of Olympic athletes in each country (as a % of GDP); unfortunately there is no consistent and sufficiently comprehensive data on this, but comparatively high levels of corporate sponsorship may help to explain why the US medal share remains so high;
- **the relative effectiveness of this funding**, which could reflect the extent to which it has been focused on building up successful sporting clusters of genuine world class, as has been the highly targeted strategy followed by UK Sport in relation to recent Olympic Games, rather than being more widely dispersed across a range of different sports; it would also reflect the effectiveness of sports administrations in different countries; and
- **the relative importance given to athletics and other Olympic sports** where significant numbers of medals are at stake (e.g. swimming, cycling, sailing, shooting, amateur boxing and rowing), as opposed to other sports which are either not represented at the Olympics (e.g. American football and cricket) or where relatively few medals are at stake (e.g. football and basketball given that team medals only count as one in the medal tables). This is likely to be related to a complex mix of historical and cultural factors as, indeed, will be the importance given to sport per se in different societies.

It follows that, if a country's performance at the Olympics differs significantly from what our economic model would predict, this could have some policy implications in relation to the level and effectiveness of sports funding as compared to other countries.

We should also mention that there are important outstanding issues at present relating to past and potential future anti-doping decisions. In particular, at the time of writing, it is unclear whether the Russian athletics team, as well as some other individual competitors from a range of sports and countries, will be allowed to compete in Rio. For the purposes of the present analysis, we have made the working assumption that Russian athletes will compete, but this is purely an assumption that makes model comparisons with past Games easier. If, for example, Russian athletes were not able to compete, as compared to winning 17 track and field medals in London, then this would boost the expected medal totals of other countries that are strong in track and field events, such as the US, Jamaica, Kenya⁶, Germany, Ethiopia and Great Britain.

⁶ The IAAF have also expressed serious concerns about the anti-doping testing regime in Kenya, but our understanding at the time of writing is that Kenyan athletes will still be allowed to compete in Rio.

Model estimates of medal targets for Rio 2016

If we apply the model to the latest available data for each country, we obtain estimated medal targets for Rio 2016 as shown in Table 1 (assuming that the total number of medals awarded is the same⁷ as in London to allow direct comparison with results from 2012).

These model estimates represent one possible benchmark or target against which to calibrate how well a country does at the Rio Olympics given its size, income levels and past performance. We would note in particular that:

- as host country, a lot of attention will be on Brazil, where our model indicates a target for around 25 medals in Rio;
- China did well as the host nation in Beijing, topping the table on gold medals and not far behind the USA on total medals won; however, it fell behind somewhat in London and we would expect the USA to top the table again in Rio with around 108 medals as compared to 98 for China;
- Russia is projected by the model to continue to be in third place in Rio (with 70 medals), although its total number of medals has tended to drift down over time relative to the heights of its performance in the old USSR era and this could fall further depending on the outcome of pending anti-doping investigations as mentioned above;
- Great Britain did exceptionally well in London, winning a record total of 65 medals, but this could fall to 52 medals in Rio given it would no longer have home advantage; this should still, however, give Team GB clear fourth place in the overall medals table, which would beat its performance at any recent Olympics prior to London 2012 (e.g. the 47 medals won in Beijing);
- the two countries with by far the largest populations in the world are China and India, but their past Olympic performances could be not be more different: China is very strong as noted above, while India won only 6 medals in London (though this was an improvement on just 3 medals in Beijing and only one medal in Athens); our model suggests that India still has significant room to improve, with a model estimate of around 12 medals for Rio. But this target could prove challenging given that, with the exception of hockey, Indian sport tends to be focused on events that are not included in the Olympics, most importantly cricket;
- our model estimates suggest that larger Western European countries such as France, Italy and Spain may broadly match their London 2012 performances in Rio, although Germany may see a small fall in its medal total from 44 to 40; and
- Australia has been in gradual decline since its high point in Sydney, but this time we expect it to perform broadly in line with London, winning around 35 medals in Rio.

Overall our model estimates suggest that the top 30 countries might be expected to win around 80% of all the medals awarded in Rio. This also broadly mirrors the shape of the global economy, in which the top 30 countries account for just over 80% of world GDP.

⁷ In practice, there may be a small increase in the total number of medals awarded in Rio, but there is unlikely to be a large change.

Table 1: Model estimates of Rio 2016 Olympics medal totals as compared to London 2012 results

Country	Model estimate of medal total in Rio 2016	Medal total in London 2012	Difference
1. USA	108	103	+5
2. China	98	88	+10
3. Russia	70*	81	-11
4. Great Britain	52	65	-13
5. Germany	40	44	-4
6. Australia	35	35	0
7. France	34	34	0
8. Japan	33	38	-5
9. South Korea	27	28	-1
10. Italy	26	28	-2
11. Brazil	25	17	+8
12. Ukraine	20	20	0
13. Canada	17	18	-1
14. Netherlands	17	20	-3
15. Spain	17	17	0
16. Cuba	16	15	+1
17. Belarus	13	12	+1
18. Hungary	13	18	-5
19. India	12	6	+6
20. Kazakhstan	12	13	-1
21. Kenya	11	11	0
22. Jamaica	10	12	-2
23. New Zealand	10	13	-3
24. Poland	10	10	0
25. Iran	8	12	-4
26. Romania	8	9	-1
27. Azerbaijan	8	10	-2
28. Czech Republic	8	10	-2
29. Denmark	7	9	-2
30. Turkey	7	5	+2
Top 30 total medals	771	801	-30
Other countries	190	160	+30
Total medals	961	961	0

Note: the table shows rounded medal estimates from the model, but the country rankings reflect unrounded model estimates.

*This assumes Russian track and field athletes are allowed to compete in Rio, which is unclear at the time of writing pending the outcome of IAAF anti-doping investigations.

Source: PricewaterhouseCoopers model estimates using data for actual medals won in London 2012 that takes accounts of medals reallocated after the Games (e.g. due to drug use violations) where a firm decision has been made on this by the Olympic authorities as of late May 2016. For the sake of comparability, we assume the same total number of medals are awarded in Rio as in in London.

Annex: Technical details of regression model

Table 2 below shows results for our preferred regression equation. This model includes performance at the previous two Olympic Games as additional independent variables together with GDP and host country status. It has much higher overall explanatory power than a model without historic performance (as indicated by the respective adjusted R-squared coefficients of 0.97 for our preferred model, as against 0.51 for a model excluding historical performance but with an ex-Soviet bloc dummy included). Since the unadjusted model estimates for medal shares in Rio did not add up exactly to 100%⁸, a small scaling factor was applied to give the results shown in Table 1.

Table 2: Regression results for preferred model (dependent variable = % medal share)

Explanatory variables	Model with past Olympic performance variables
Constant	0.0003
Level of GDP at PPPs (\$ trn)	0.001 (3.6)
Ex-Soviet bloc dummy	Not significant
Host country dummy	0.02 (9.0)
Medal share in previous Olympic Games	0.508 (7.8)
Medal share in previous but one Olympics Games	0.351 (6.4)
<i>Explanatory power (adjusted R-squared)</i>	<i>0.97</i>
<i>Standard error of model</i>	<i>0.0029</i>
<i>Number of countries covered</i>	<i>109</i>

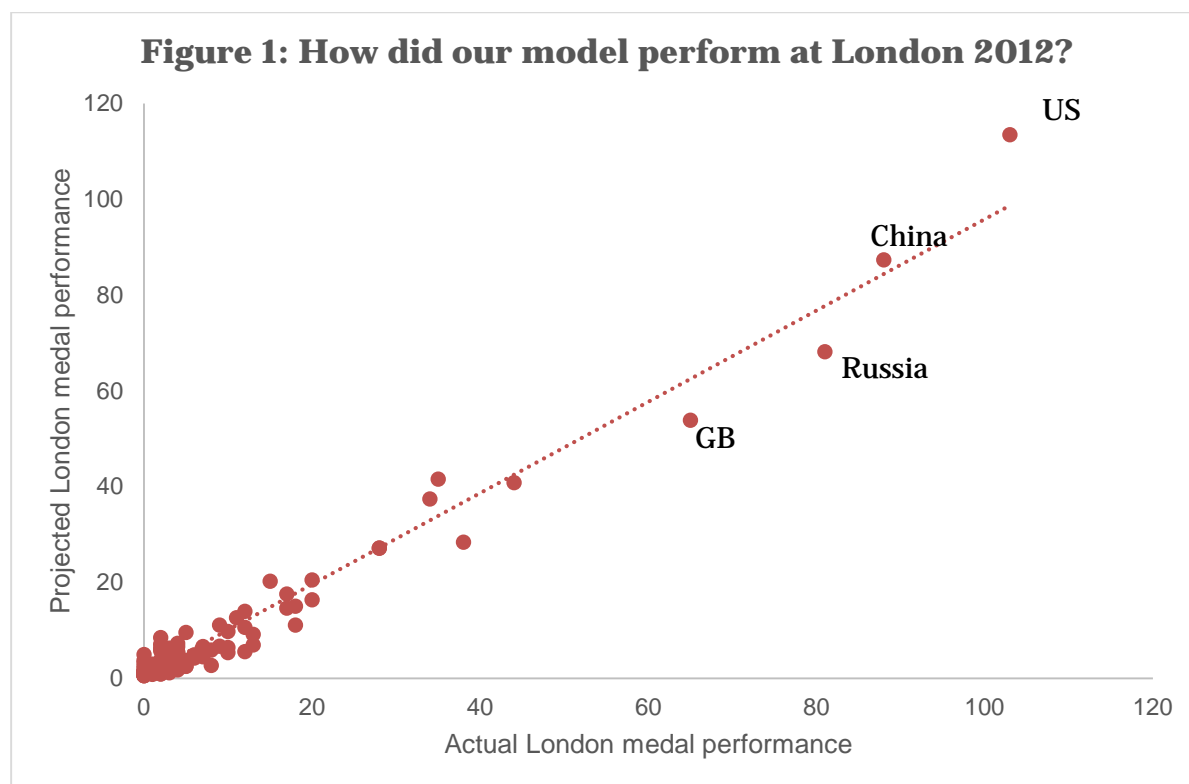
Note: t-statistics shown in brackets for explanatory variables

Source: PwC analysis using data from 109 medal-winning countries in 2000, 2004, 2008 and 2012 Olympics, plus IMF data on GDP at PPP exchange rates. For the Rio projections in Table 1 above, the London 2012 and Beijing 2008 Olympics results were factored into this model together with the latest IMF GDP estimates for 2015.

As indicated by t-statistics, all explanatory variables in the preferred model variants were statistically significant at the 99% confidence level.

Figure 1 on the next page gives a visual indication of how the model we developed before the 2012 London Games did in predicting actual medal totals there. We can see from this chart that there was a reasonably good fit with actual performance but also some variations. The model projected the performance of China very well, but the US was an underperformer in London relative to what the model would have suggested, while Russia and Great Britain outperformed our model projection. But the ordering of the top countries was correct.

⁸ The unadjusted medal shares added up to around 101%, so these were all scaled down by a factor of 1.01 to give the results in Table 1. The total number of medals in Rio has been set to 961, the same as were awarded in London.



We have now re-estimated our model to take account of the new data on actual performance at London 2012, so we might hope for an even better predictive performance in Rio 2016. But there will always be unexpected factors at Olympic Games, which is why we regard our model projections in Table 1 above as benchmarks against which to judge performance, rather than precise forecasts.

Contacts and services

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John is chief economist in our UK firm and works in our Economics and Policy practice. This offers a wide range of services covering: market reform in a range of industry sectors (including energy, water, media and telecoms, financial services, health and government services); competition policy, disputes and other investigations; economic, social and environmental impact analysis; financial economics; fiscal policy and macroeconomics. This practice forms part of Strategy&, PwC's strategy consulting business.

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