GLOBAL TALENT FUND

FROM MEDALS TO MOMENTUM: CAN BETTER INTERNATIONAL MATH OLYMPIAD SCORES DRIVE CHANGE?

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ABSTRACT

This paper analyzes the performance and outcomes of countries in the International Math Olympiad (IMO) from the early 2000s to the 2020s, using a novel dataset of participants' career outcomes. Cross-country data with a focus on six case study countries — Cuba, Georgia, Saudi Arabia, Sri Lanka, the Philippines, and Tunisia — forms the basis of the analysis, yielding three key results: 1) Country rankings are highly persistent, with 90% of the top third remaining in the top third after 20 years. 2) Despite this, about 10.7% of countries from the middle group, including France, Italy, and Mongolia, moved to the top third, and 40% of countries in the bottom group, including the Philippines and Tunisia, improved to the middle third. 3) Among the countries that improved, later cohorts are more likely to achieve higher scores, win medals, pursue undergraduate education abroad, and attend Top100universities. These findings provide insights into how countries can leverage improved IMO performance for broader educational and developmental goals.

Keywords

Olympiads, economics of talent, talent economics, human capital, education and growth, cross-country comparisons

JEL Codes

I23, J24, O47

1 Introduction

The development of top talent, particularly in fields that drive innovation and economic growth, has become a critical area of study. This paper presents an empirical investigation into the determinants of top talent generation, with a focus on two primary factors: population size and income. Using data from the International Science Olympiads and the Sports Olympics, we examine the relationship between these factors and the cultivation of elite talent across countries.

The International Science Olympiads include the International Biology Olympiad (IBO), the International Chemistry Olympiad (IChO), the International Mathematical Olympiad (IMO), the International Olympiad in Informatics (IOI), and the International Physics Olympiad (IPhO). These Olympiads are globally recognized competitions that showcase the mathematical and scientific abilities of high school students. The Olympic Games, commonly referred to as the Olympics, are international sports competitions held every four years, divided into the Summer and Winter Games, with participants from around the world.

Several studies have examined the varied performance of individuals across countries and the underlying factors. For example, Hyde and Mertz (2009) analyzes the role of gender and culture in student performance at the IMO, while Agarwal and Gaulé (2020) and Agarwal et al. (2023) explore the relationship between IMO performance, mathematics knowledge production, and U.S. immigration. In addition, Trivedi and Zimmer (2014) investigates the impact of economic factors on performance in seven Summer Olympics. In this paper, we aim to identify the determinants of performance across all Science Olympiads and both the Summer and Winter Olympics, highlighting how to assess countries' utilization of their resources. Our findings highlight population and income as key factors in innovation, identify the largest gaps in the talent pipeline, and suggest that targeted investments in these areas could yield substantial returns.

We introduce the concept of a "talent frontier," a benchmark representing the highest achievable use of a country's population and income resources in developing talents. This benchmark allows for measuring countries' efforts and outcomes in talent development. Based on a country's population size and income, we predict its performance in international competitions, assess how far countries are from the talent frontier, and evaluate how effectively they utilize their resources to foster top talent. Our analysis provides insights into the strategic resource allocation for education and training, emphasizing their potential impact on both national and global innovation.

1.1 Data

To create the original dataset for this paper, we combine multiple data sources. We collect data on all Science Olympiads participants from the official websites (http://www.ibo.org, http://www.icho-official.org, http://www.imo-official.org, http://www.ioinformatics.org, and http://www.ipho-official.org), selecting only data for students who participated since 2000. This

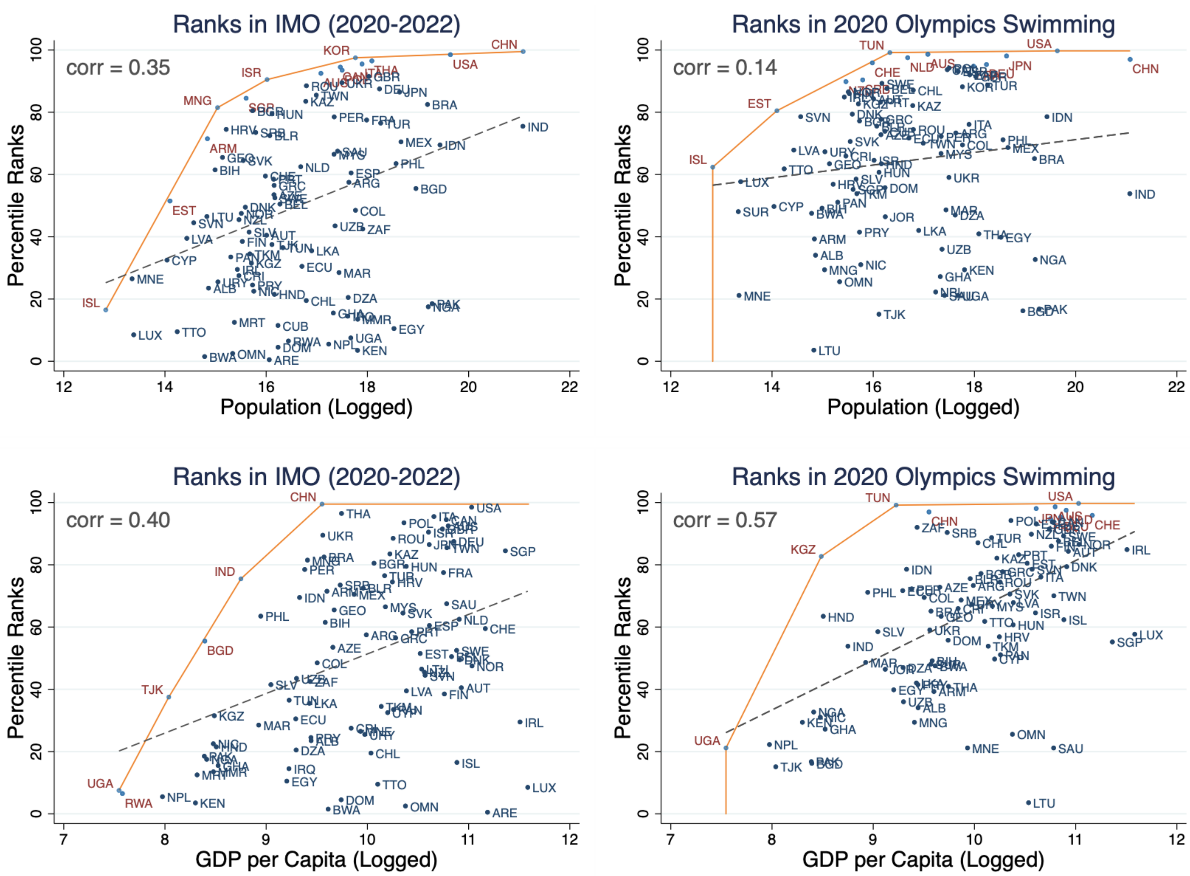

Figure 1: Elite performance vs. Population and income

Notes: The figure presents scatter plots comparing country percentile ranks based on average ranks from the 2020-2022 period for the IMO and the 2020 Olympics swimming, against logged population and income (GDP per capita in terms of USD). The first row shows the correlations between percentile ranks and population, while the second row displays the correlations with income. Frontier countries are highlighted with light blue markers and red font. These countries were selected if their distance from the frontier lines was less than 5 percentage points. A methodology note on how to identify frontier countries is provided in Appendix.

dataset includes 33,910 individuals from 138 countries, with information on the year, country, points scored, ranks, and type of medal obtained by each participant.

We then combine the Science Olympiads data with the Olympic Games dataset to create the final dataset for this paper. The Olympic Games data is sourced from the official Olympics website (https://olympics.com) and includes information on all participants since 1896, such as the year, country, ranks, medals obtained, and sports records. This dataset contains 318,890 individual records, which we use to calculate the average individual performance for 227 countries.

Finally, we combine data from international competitions with country-level economic and environmental indicators — population size, GDP per capita (in U.S. dollars), the human capital index, and average temperature — to examine how these factors affect countries' performance in these competitions. The economic indicators and temperature data are sourced from the World Bank Indicators, specifically using information from 2020.

2 What Factors Drive Elite Performance?

We begin by highlighting the significant role of population and income in determining countries' performance in both scientific and athletic international competitions. Figure 1 illustrates the relationship between the percentile ranks of countries that participated in the IMO from 2020 to 2022 and the 2020 Olympics swimming events. The scatter plots compare the countries' percentile ranks, calculated based on their average ranks of these competitions' participants, against the logged population and logged GDP per capita in U.S. dollars. The figure shows a positive correlation between the ranks and these indicators, indicating that larger and wealthier countries tend to perform better in these competitions. Notably, the second row of the figure shows that this relationship becomes stronger when comparing the ranks with GDP per capita.

In the figure, frontier countries — those that make the most effective use of their population and income — are labeled in red font with blue markers. An envelope is also drawn to connect these frontier countries. Details about identifying frontier countries are presented in the Appendix. These countries are considered "at the frontier" because, given certain levels of population and income, they outperform other countries. For example, the United States and China are consistently close to the frontier line, indicating high percentile ranks compared to other countries with similar population and income levels.

Based on this observation, we present formal regression results in Table **??** to show the impact of population and income on performance in international science and sports competitions. The table reports the effects of population, income, and the human capital index on the average percentile ranks of countries participating in the Science Olympiads, as well as the Summer and Winter Olympics. The dependent variable is the percentile rank of each country, based on the average rankings of their participants in these competitions. For the Science Olympiads, we consider five different science competitions, while for the Olympics, we distinguish between the Summer and

Table 1: What affects countries' performance in international competitions - Percentile ranks

	Science Olympiads		Summer Olympics		Winter Olympics			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Population (logged)	0.98***	0.98***	0.95***	0.97***	0.87***	0.89***	0.98***	0.99***
	(0.01)	(0.01)	(0.01)	(0.02)	(0.04)	(0.03)	(0.02)	(0.02)
Income (logged)	0.92***	0.40***	1.64***	0.40***	1.76***	0.93**	1.84***	1.02***
	(0.04)	(0.04)	(0.10)	(0.09)	(0.04)	(0.03)	(0.12)	(0.23)
Human capital index		56.8***		134.0***		86.0***		83.8***
		(2.57)		(10.2)		(20.4)		(13.1)
Temperature							-1.10***	-1.99***
							(0.10)	(0.09)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Olympiad FE	Yes	Yes	No	No	No	No	No	No
Sport FE	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Region FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observation	1,878	1,878	475	475	353	353	353	353
R2	0.61	0.62	0.65	0.70	0.68	0.70	0.67	0.69

Notes: The table presents regression results with year, competition, and region fixed effects. Olympiad fixed effects, including IBO, ICHO, IMO, IOI, and IPHO, are included for the Olympiads, while sport fixed effects are included for the Olympics. Region fixed effects are included, as defined by the World Bank. The dependent variable is country percentile ranks based on average ranks from the 2000-2022 period for the Olympiads and from the 1896-2022 period for the Olympics. "Population" refers to the logged population, and "Income" refers to logged GDP per capita. Standard errors are clustered by years. *** $p < 0.01$ ** $p < 0.05$ * $p < 0.1$.

Winter Games. The period spans from 2000 to 2022 for the Science Olympiads and from 1896 to 2022 for the Olympics. The independent variables, including population, income, and the human capital index, are based on data from 2020. For the Winter Olympics, we conduct additional analyses by controlling for the average temperature of each country, given the historical observation that countries with warmer climates tend to perform poorly in the Winter Olympics. Regression results using the number of medals obtained as the dependent variable are provided in the Appendix.

The table shows that both population and income significantly affect a country's performance in these international competitions. Across all competitions, a 10 percent increase in population is associated with roughly a 0.1 point increase in a country's percentile rank. In the Winter Olympics, the effect of population remains close to 0.1 points even after controlling for a country's average temperature. For income, a 10 percent increase in GDP per capita corresponds to about a 0.04 point higher rank in the Science Olympiads and Summer Olympics, and about a 0.1-0.2 point higher rank in the Winter Olympics, depending on the specification. In the case of the Winter Olympics, each 1°C increase in a country's average annual temperature is associated with a 1–2 point decrease in its percentile rank, in line with common expectations. The human capital index positively impacts performance across all international competitions.

3 Which Countries Exceed or Fall Short of Expectations?

While population, income, temperature, and human capital are important factors in determining a country's performance in the Science Olympiads and Olympic Games, other factors also contribute. Figure 1 shows that even countries with similar population sizes or GDP per capita can have varying percentile ranks. We define "frontier countries" as those with the highest percentile ranks after controlling for these factors, indicating that they make the most effective use of their available resources. In this section, we examine which countries excel at utilizing their resources to develop talent in both science and sports.

First, we calculate the predicted percentile ranks using the following regression model:

$$\text{Predicted percentile rank} = \beta_1 \cdot ln(\text{population}) + \beta_2 \cdot ln(\text{income}) + \gamma \quad (1)$$

where "Predicted percentile rank" represents the expected percentile rank, calculated based on a country's population and income. We then compute the "Distance" from prediction as:

$$\text{Distance} = \text{Actual} - \text{Predicted percentile rank} \quad (2)$$

where "Actual" is the actual observed average percentile rank of countries in international competitions, and "Predicted percentile rank" refers to the predicted value obtained from Eq. (1). Countries with the largest positive distance from their predicted percentile rank can be referred to

Table 2: Over- and under-performing countries

		Science Olympiads		Summer Olympics		Winter Olympics	
		Country	Distance	Country	Distance	Country	Distance
Over-performing	1	Russian Federation	46.6	Montenegro	52.6	Paraguay	58.4
	2	South Korea	40.8	Honduras	52.4	Jamaica	56.5
	3	Armenia	38.2	Mongolia	47.7	Madagascar	47.5
	4	Ukraine	38	Kyrgystan	45.9	Trinidad and Tobago	35.6
	5	Serbia	34.8	Zimbabwe	43	Nigeria	29.9
	6	Tajikistan	34	Serbia	39.6	Sweden	29.9
	7	Mongolia	33.9	Angola	38.2	Russian Federation	29.8
	8	Thailand	32.2	Tunisia	37.2	China	29
	9	Belarus	31.7	New Zealand	33.4	South Korea	28
	10	Bulgaria	31.7	Croatia	29.6	Norway	27.1
	11	Romania	31.6	Iraq	29.5	Finland	26.7
	12	Hungary	30.4	Argentina	26	Latvia	25.8
	13	Georgia	29	Denmark	25.9	Belarus	24.6
	14	Croatia	27.3	Pakistan	24.8	Netherlands	24.4
	15	Estonia	25.2	Georgia	24	Canada	23.7
	16	Peru	24	Russian Federation	23.5	Germany	22
	17	Taiwan	23.5	Hungary	22.8	Denmark	21
	18	Indonesia	23.4	South Korea	21.8	Japan	19.9
	19	Singapore	23.3	Sweden	20.3	Nepal	19.1
	20	Kazakhstan	22.6	Jordan	20.1	Switzerland	18.9
Under-performing	1	Ireland	-41.7	Oman	-48.5	Luxembourg	-60.9
	2	United Arab Emirates	-38.3	Bangladesh	-46.1	Malaysia	-47.8
	3	Angola	-37.3	Ghana	-43.3	South Africa	-43.8
	4	Iraq	-35.5	Mauritania	-39.1	Cyprus	-43.6
	5	Algeria	-33.3	Trinidad and Tobago	-37.7	Ireland	-35.4
	6	Kenya	-31.1	Saudi Arabia	-37.6	Ecuador	-35.2
	7	Chile	-30.6	Turkmenistan	-36	Philippines	-34.9
	8	Botswana	-29.7	Costa Rica	-32.5	Mexico	-34.1
	9	Panama	-28.5	Panama	-31.6	Turkey	-32.2
	10	Oman	-28.4	Turkey	-27.9	Thailand	-32
	11	Myanmar	-28.3	Sri Lanka	-26.3	Brazil	-29.2
	12	Kuwait	-27.4	Qatar	-24.9	Morocco	-27.8
	13	Guatemala	-27.3	Cyprus	-23.3	Serbia	-26.3
	14	Luxembourg	-25.1	The Gambia	-22.9	Azerbaijan	-24.2
	15	Norway	-22.8	Tajikistan	-21.8	Bosnia and Herzegovina	-24.1
	16	Dominican Republic	-22.2	Switzerland	-20.4	Albania	-23.9
	17	Paraguay	-22	Uganda	-20.1	North Macedonia	-23.8
	18	Ecuador	-21.2	Philippines	-20	Argentina	-21.7
	19	Ghana	-20.8	Bosnia and Herzegovina	-19.9	Colombia	-21.3
	20	Spain	-19.7	Nigeria	-19.7	Iceland	-21.3

Notes: The table presents 20 over-performing and 20 under-performing countries based on population and income. "Over-performing" countries are those with the smallest distance from predictions based on population and income, while "Under-performing" countries are those furthest from the prediction. "Distance" indicates the percentage points a country deviates from the predicted percentile rank. The period spans from 2010 to 2022. The list of over-performing and under-performing countries for the Winter Olympics, after controlling for average temperature, is provided in the Appendix.

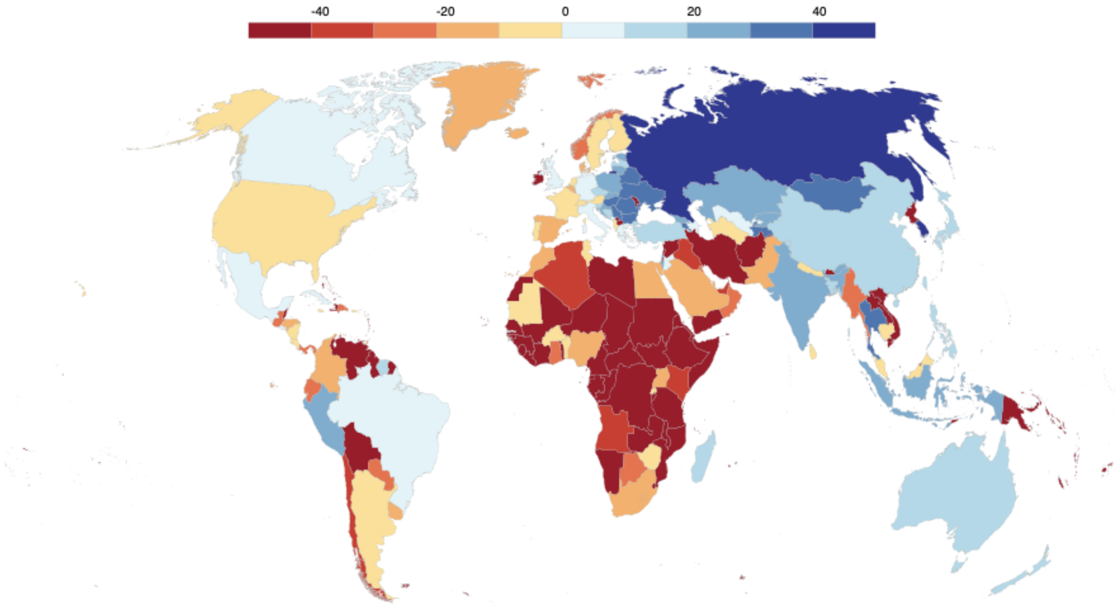

Figure 2: Distances from Predictions: Science Olympiads

Notes: The map shows the difference between the actual and predicted percentile ranks. For example, a value of 40 indicates that a country's percentile rank is 40 percentage points higher than the predicted rank. The sample period covers Science Olympiads from 2010 to 2022. The predictions are made based on country population and income.

as frontier countries.

Table 2 shows the countries with the largest deviations from their predicted performance in the Science Olympiads and Olympic Games. A positive deviation indicates that a country's observed percentile rank is higher than predicted, while a negative deviation suggests lower-than-expected performance. The table highlights 20 over-performing countries (with positive deviations) and 20 under-performing countries (with negative deviations). Although the list of countries varies across competitions, there is some overlap, such as the Russian Federation and South Korea, which appear as over-performing countries in both the Olympiads and the Olympics.

To further examine which countries exceed or fall short of expectations, Figures 2-4 provide visual maps showing the deviations for each competition. The maps reveal similar distribution patterns across competitions, with generally higher values in North America, East Asia, and Oceania. Even after controlling for income and population, many large and high-income countries show positive deviations from their predicted performance, while small and low-income countries show negative deviations. However, there are notable differences between the competitions. For example, weather conditions significantly impact performance in the Winter Olympics, where countries closer to the equator have fewer opportunities to develop talent in winter sports. In

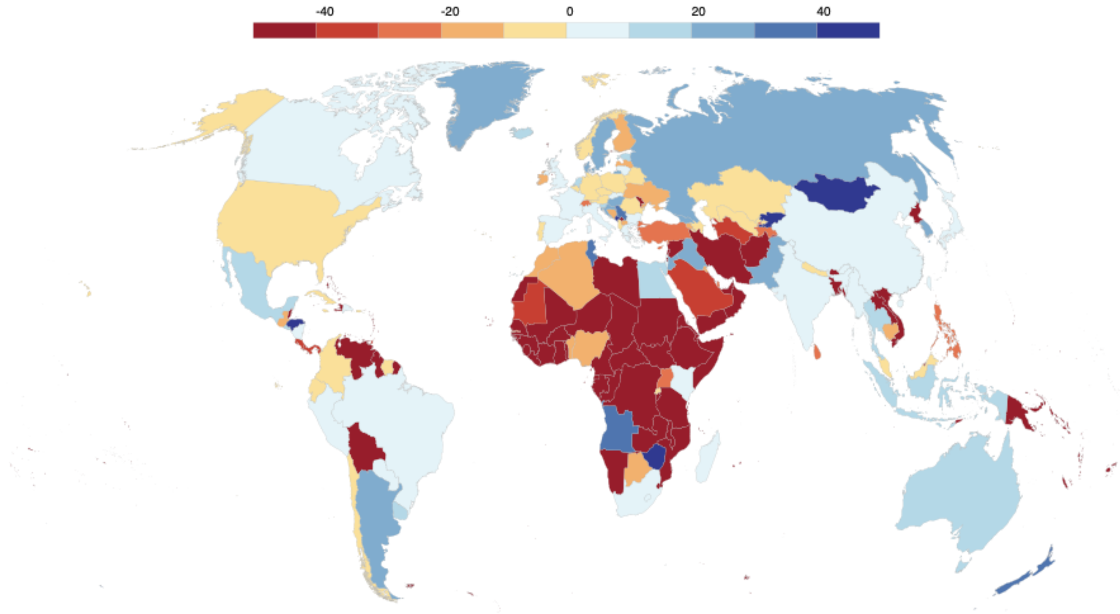

Figure 3: Distances from Predictions: Summer Olympics

Notes: The map shows the difference between the actual and predicted percentile ranks. For example, a value of 40 indicates that a country's percentile rank is 40 percentage points higher than the predicted rank. The sample period covers Summer Olympics from 2010 to 2022. The predictions are made based on country population and income.

contrast, in the Summer Olympics, countries with hot climates do not necessarily perform better. Countries in Africa, South America, and Southern Asia tend to show large negative deviations from the expected percentile ranks in the Winter Olympics, suggesting that, even after controlling for income and population, weather is a crucial factor influencing a country's performance in these competitions.

Since the Summer and Winter Olympics focus on athletic talent and the Science Olympiads emphasize scientific intellectual talent, it might be assumed that the type of talent affects each country's performance and resource allocation. This would suggest that some countries excel in fostering athletic talent, while others prioritize developing intellectual talent. Consequently, we might observe that countries with high percentile ranks in the Summer Olympics also perform well in the Winter Olympics but not necessarily in the Science Olympiads, allowing us to distinguish between the Science Olympiads and the Sports Olympics when identifying frontier countries.

However, Table 3 shows that the deviations from predicted performance in the Summer Olympics are more closely correlated with those in the Science Olympiads than with the Winter Olympics. There is a significant positive correlation of 23% between the deviations in the Science Olympiads and the Summer Olympics, whereas the deviations in the Winter Olympics do not show

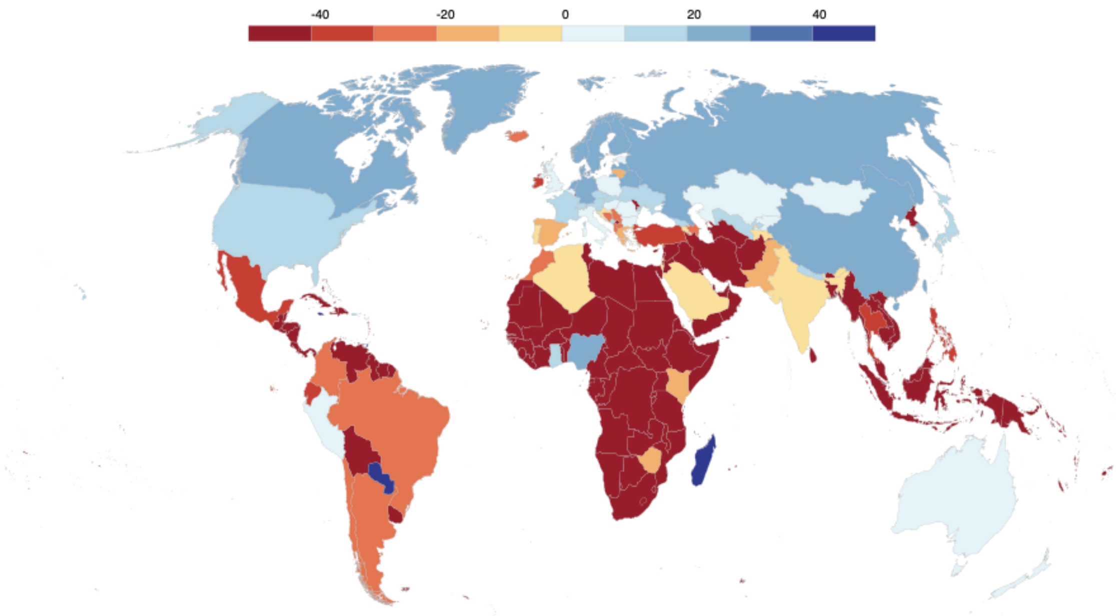

Figure 4: Distances from Predictions: Winter Olympics

Notes: The map shows the difference between the actual and predicted percentile ranks. For example, a value of 40 indicates that a country's percentile rank is 40 percentage points higher than the predicted rank. The sample period covers Winter Olympics from 2010 to 2022. The predictions are made based on country population and income.

Table 3: Correlations between distances from predictions at Science Olympiads and Olympics

	Science Olympiads	Summer Olympics	Winter Olympics
Science Olympiads	1		
Summer Olympics	0.23**	1	
Winter Olympics	0.16	0.05	1

Notes: The table presents correlations between percentage point distances from predicted percentile ranks for the Science Olympiads, Summer, and Winter Olympics. The sample period spans from 2010 to 2022. *** $p < 0.01$ ** $p < 0.05$ * $p < 0.1$.

a significant relationship with those in either the Science Olympiads or the Summer Olympics. This suggests that factors beyond the specific type of competition play a stronger role in determining performance.

4 Conclusion

This paper explored the factors affecting elite performance in international Science Olympiads and Olympic sports, with a focus on the effects of population size and income. Our findings showed that both factors are crucial for success, though income often has a stronger impact. We observed that many countries in Africa and the Middle East tend to use their resources less effectively, whereas countries in North America and East Asia perform better across various competitions. However, some countries with strong traditions in sports achieve exceptional results. Moreover, we found a moderate correlation between success in the Science Olympiads and the Summer Olympics, suggesting that shared influences — potentially education systems, government policies, or cultural values — may be at play across these different areas, indicating that high resource levels are not enough to exactly predict success.

These findings have important implications. The recurring under-performance of certain regions indicates a significant potential for many developing countries to enhance how they utilize their talent. The observed correlation between science and sports performance suggests that a more comprehensive approach to nurturing talent, spanning different fields, could be beneficial. Strategies such as enhancing educational infrastructure, providing broader access to quality training, and fostering a culture that values multiple forms of excellence could be effective strategies for achieving these goals.

Future research should aim to uncover the specific factors contributing to the under-performance in particular regions. This could involve exploring the impact of government investment in education and sports, the role of social and cultural norms, or the effects of geopolitical circumstances. Moreover, further analysis of why countries with similar economic conditions achieve different results could provide valuable insights into the broader determinants of elite performance. Understanding these factors would enable policymakers and stakeholders to design more effective strategies to help countries fully leverage their potential and achieve greater success on the international stage.

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Appendix

A.1 Identifying Frontier Countries

In this section, we outline the methodology used to identify frontier countries, as illustrated in Figure 3. To make the process more intuitive, we use percentile ranks to rank countries participating in each international competition, including the Science Olympiads and the Olympic Games, rather than inverse ranks. Higher percentile ranks indicate better performance in these competitions. We also assess how well countries utilize each of their resources to check for any patterns of consistency.

The methodology involves the following steps:

1. Calculate the Average Ranks: Determine the average ranks of participants from each country in each international competition.

2. Calculate Percentile Ranks: Compute each country's percentile rank among all participating countries for each competition, including the Science Olympiads, the Summer Olympics, and the Winter Olympics.

3. Apply Data Envelopment Analysis (DEA): Use the DEA method to create an envelope on a scatter plot of percentile ranks versus economic indicators, such as population and income. This step identifies frontier countries that achieve the highest percentile ranks within their population or income group.

4. Identify Additional Frontier Countries: Locate additional frontier countries that are within 5 percentage points of the envelope determined in Step 3.

After identifying the frontier countries, we perform regression analysis to make predictions on expected percentile ranks for these competitions, considering both population and income. The frontier countries, which exhibit the greatest deviation from predicted percentile ranks, are categorized as over-performing countries. Conversely, countries with lower percentile ranks than expected for their level of income and population are classified as under-performing countries, as detailed in the main text.

A.2 Appendix Tables

Table A.1: What affects countries' performance in international competitions? - # Medals

	Science Olympiads		Summer Olympics		Winter Olympics			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Population (logged)	0.26***	0.26***	0.06***	0.06***	0.05***	0.05***	0.07***	0.07***
	(0.002)	(0.003)	(0.005)	(0.005)	(0.002)	(0.002)	(0.004)	(0.004)
Income (logged)	0.22***	0.12***	0.15***	0.10***	0.18***	0.17***	0.14***	0.13***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.01)	(0.01)
Human capital index		10.92***		4.70***		0.45		0.35
		(2.57)		(0.91)		(1.65)		(0.67)
Temperature							-0.05**	-0.05**
							(0.01)	(0.01)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Olympiad FE	Yes	Yes	No	No	No	No	No	No
Sport FE	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Region FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observation	1,878	1,878	475	475	353	353	353	353
R2	0.57	0.57	0.45	0.45	0.46	0.46	0.64	0.64

Notes: The table presents regression results with year and competition fixed effects. Olympiad fixed effects, including IBO, ICHO, IMO, IOI, and IPHO, are included for the Olympiads, while sport fixed effects are included for the Olympics. Region fixed effects are included, as defined by the World Bank. The dependent variable is the total number of medals obtained from the 2020-2022 period for the Olympiads and from the 1896-2022 period for the Olympics. "Population" refers to the logged population, and "Income" refers to logged GDP per capita. Standard errors are clustered by years. *** $p < 0.01$ ** $p < 0.05$ * $p < 0.1$.

Table A.2: Over- and under-performing countries in Winter Olympics: Controlling temperature

	Over-performing		Under-performing	
	Country	Distance	Country	Distance
1	Paraguay	65.1	Luxembourg	-56.6
2	Jamaica	64.7	South Africa	-43.1
3	Trinidad and Tobago	46.9	Malaysia	-39.0
4	Madagascar	46.8	Cyprus	-37.2
5	Nigeria	33.7	Turkey	-34.6
6	Swden	24.6	Ireland	-33.8
7	Netherlands	24.6	Ecuador	-31.8
8	Latvia	23.5	Mexico	-30.6
9	Singapore	22.6	Philippines	-29.8
10	Norway	22.1	Serbia	-27.5
11	Finland	21.3	Morocco	-27.3
12	Denmark	20.7	Bosnia and Herzegovina	-25.6
13	Belarus	20.4	Iceland	-25.0
14	Germany	20.1	Azerbaijan	-24.8
15	China	19.7	Chile	-24.8
16	Ghana	19.2	North Macedonia	-24.7
17	Japan	18.3	Thailand	-24.5
18	Switzerland	17.6	Albania	-24.3
19	Uzbekistan	16.1	Brazil	-23.9
20	France	14.5	Argentina	-22.0

Notes: The table presents 20 over-performing and 20 under-performing countries based on population and income, controlling for countries' average temperature. "Over-performing" countries are those with the smallest distance from predictions based on population and income, while "Under-performing" countries are those furthest from the prediction. "Distance" indicates the percentage points a country deviates from the predicted percentile rank. The period spans from 2010 to 2022.