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Who'll Win in Los Angeles?

Summary

The Olympic Games are a globally followed event, with the medal table serving as a key point of interest for fans.In the Paris 2024 Olympics, the United States and China led the medal tally, while France and Great Britain also made notable achievements. This paper develops a predictive model based on historical data to forecast the 2028 Los Angeles Olympics medal counts for individual countries.

Firstly, we developed a medal prediction model based on country performance, sport-specific indicators, and individual momentum, aimed at forecasting the 2028 Los Angeles Olympics medal distribution and estimating prediction intervals. Results indicate that the U.S. will maintain a leading position in total medals due to its host advantage, with China ranked second, but with a decline in medal count from 2024. Japan and South Korea are expected to see increases in medal counts, particularly Japan.

Secondly, we evaluates the likelihood of countries that have not yet won medals earning their first medal in 2028, predicting higher probabilities for countries such as Palestine, Guinea-Bissau, and Papua New Guinea to win their first medal.

Thirdly, we analyzed the effect of the number and type of events on the medal distribution and found that increasing the number of athletics, judo and shooting events would significantly improve the gold medal advantage in the US and China.

Fourthly, we also explores the impact of the "Great Coach" effect on Olympic medal counts. By analyzing the cases of Lang Ping and Béla Károli, it reveals the role of top coaches in enhancing athletes' personal momentum in the short term and improving sport-specific performance in the long term. Based on data analysis, we recommends that the United States, China, and Japan invest in "Great Coach" for sports such as taekwondo and volleyball to enhance performance in these areas and drive medal growth.

Finally, we highlights how event selection and emerging sports affect Olympic medal distribution. Expanding events in resource-heavy sports like athletics and weightlifting benefits dominant countries, while the introduction of low-cost sports like surfing and skateboarding offers new medal opportunities for smaller nations. Emerging sports, requiring fewer resources, give countries with natural advantages a competitive edge. Olympic committees should advocate for expanding events in traditional strengths and include new sports to maximize medal potential, especially for resource-limited nations, offering them a chance to break into new areas of competition.

Keywords: Country; Sport-specific; Individual momentum; Trend; Coach

Contents

1 Introduction

1.1 Background

The Olympic medal table serves as a barometer of national pride and athletic excellence, influenced by a confluence of factors including economic capacity, demographic size, and strategic investment in sports. Nations with systemic advantages often dominate the standings, while smaller countries encounter significant hurdles in achieving comparable levels of success. Host nations, on the other hand, typically experience a surge in performance, benefiting from the "home advantage"—a result of increased resources, familiar environments, and heightened national support.

With advancements in data analysis, it has become possible to quantify the impact of socioeconomic indicators, event-specific specialization, and coaching expertise on medal distributions. The contributions of renowned coaches like Lang Ping and Béla Károlyi exemplify how strategic coaching can elevate national performance. Additionally, the selection of events by host nations plays a pivotal role in shaping medal outcomes.

Through a comprehensive analysis of these dynamics, Olympic committees can derive actionable insights to optimize resource distribution, pinpoint key sports for targeted investment, and formulate strategies to enhance medal prospects. This is especially important for emerging nations aiming for their first podium finishes, thereby fostering a more equitable competitive landscape.

1.2 Restatement of Problems

Based on the background and constraints outlined, we have identified the following key challenges to address:

- ✓ Develop a predictive model for medal counts by country, assessing prediction uncertainty and performance.
- ✓ Forecast the 2028 Los Angeles Olympic medal table, providing prediction intervals and analyzing potential improvements or regressions of countries.
- ✓ Estimate the number and likelihood of countries winning their first medals.
- ✓ Analyze the impact of event quantity and type on medal distribution, and assess how host country event choices affect outcomes.
- ✓ Evaluate the role of elite coaches in medal counts by selecting three countries and analyzing the potential impact of introducing such coaches.
- ✓ Identify other patterns in medal distribution and provide actionable insights for optimizing the strategies of national Olympic committees.

1.3 Literature Review

Olympic medal prediction has been approached through various methodologies, including traditional statistical models, machine learning techniques, and time series and grey system models, each with its own strengths and limitations.

Bernard and Busse applied the Cobb-Douglas production function to examine the influence of GDP, population size, and host nation status on Olympic medal counts[1]. Their findings highlighted that GDP and population size are key determinants, with host nations earning approximately 1.8% more medals due to the "host effect". Additionally, Tobit models have been used to address censored data in medal prediction, effectively handling the non-negative nature of medal counts and zero-inflated distributions. While these models offer strong interpretability, they struggle with capturing non-linear interactions and dynamic changes.

In recent years, with advancements in computational power, machine learning methods have gained traction. Schlembach et al. used a Random Forest algorithm in a two-stage prediction process, reducing prediction errors by 3%-6% compared to traditional methods[2]. Shi Huimin combined Random Forest with SHAP analysis to quantify the impact of variables like population, GDP, and event-specific advantages, offering deeper insights into prediction dynamics[3]. Noviyanti et al. compared advanced boosting algorithms—XGBoost, LightGBM, and CatBoost—finding XGBoost to have the highest accuracy, exceeding 90%[4]. Despite their high accuracy, machine learning models often lack interpretability, which limits their effectiveness in practical applications.

Additionally, Grey system theory and time series models have also been widely applied to predict medal counts. Wei Li used the Verhulst model and grey correlation analysis to forecast China's medal performance from 1984 to 2016, accounting for the "home advantage" effect. While effective for small sample sizes, this method had an error rate of 18.54%, suggesting room for improvement[5]. Similarly, Li Xiang's application of ARIMA to model France's medal trends demonstrated the strength of time series methods in capturing stable, periodic patterns, but revealed limitations in addressing complex, dynamic systems[6] .

Figure 1: Thumbnail for Literature Review

In contrast to previous studies, which either focus primarily on macro-level factors, neglecting individual athlete data and thus limiting their ability to capture dynamic changes and reducing reliability, or lack interpretability, making it difficult to offer actionable insights for national Olympic committees and sports organizations, our model takes a more holistic approach. It integrates national performance, sport-specific dynamics, and medal distribution, while incorporating historical data through methods such as exponential moving averages. Additionally, we model individual athletes using momentum to account for their dynamic progress, resulting in a model that excels in accuracy, stability, and interpretability.

1.4 Our Work

- ✧ We developed a predictive model based on historical data, integrating national performance, sport-specific dynamics and individual momentum, along with event scheduling and athlete participation, to forecast the 2028 Olympic medal table, first-time medal-winning countries and their probabilities.
- ✧ We evaluated the model's predictive accuracy and uncertainty by estimating residuals and confidence intervals for medal counts, thereby validating the model's reliability.
- ✧ Taking advantage of the model, we quantitatively analyzed the impact of event distribution on medal outcomes. Additionally, we visualized the long-term and short-term trends of different countries and qualitatively assessed the role of coaches, providing actionable recommendations for Olympic committees.

2 Assumptions and Justifications

➢ **Assumption 1:** The athletes participating in the 2028 Olympics will be the same to those in the 2024 Games.

***Justification*:** Historical trends indicate that many elite athletes compete across multiple Olympic cycles, making this assumption reasonable and simplifies the modeling process.

➢ **Assumption 2:** The prediction error follows a t-distribution $\varepsilon \sim t(v)$, with degrees of freedom v equals n - p. (n represents the sample size, and p is the number of model parameters). Its variance exhibits heteroscedasticity, but is linearly related to the number of medals.

***Justification*:** Olympic medal predictions are influenced by national factors (e.g., GDP, population, sports investment) and historical data. The t-distribution is well-suited for modeling prediction errors due to its heavy-tailed nature, which accommodates outliers, small sample sizes, and model bias more effectively than the normal distribution. Its flexible degrees of freedom make it adaptable to high uncertainty, while its robustness ensures reliable results, even in extreme cases.

➢ **Assumption 3:** An athlete's capability can be modeled as a linear combination of country, sport-specific, and individual factors. The country and sport-specific factors remain fixed as the athlete's Olympic debut year, while the individual factor evolves.

***Justification*:** The country factor reflects differences in economic development and sports participation rates across nations. The sport-specific factor accounts for genetic predispositions and strengths in particular events. The individual factor captures an athlete's historical performance and its fluctuations over time, offering a dynamic measure of their evolving potential.

3 Data Description

We exclusively utilize medal tables for all Summer Olympic Games, including information on host countries and the breakdown of Olympic events by sport for each edition, as well as official data for all individual Olympic competitors, detailing their sport and results, to build the model. Fig. 2, 3 provide visual representations of the data.

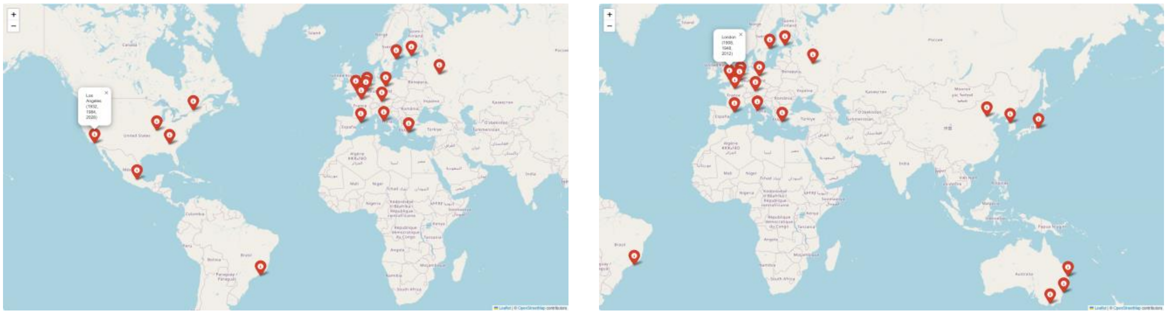
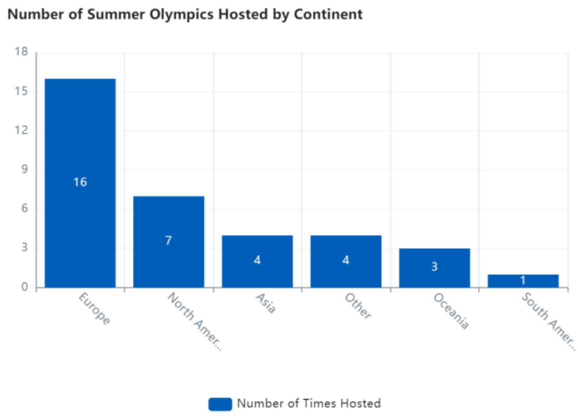
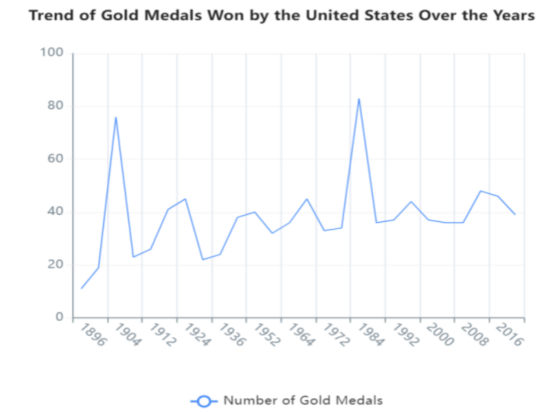


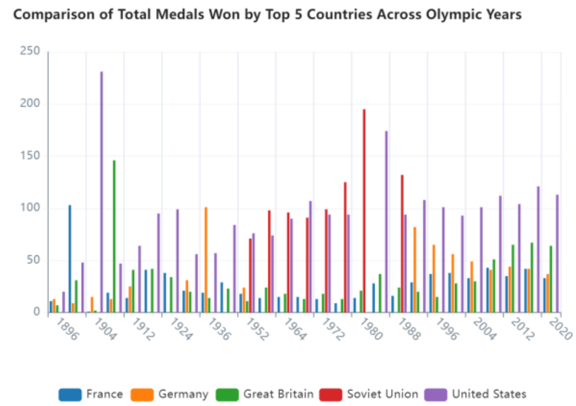
Figure 2: Distribution Map of Olympic Host Countries



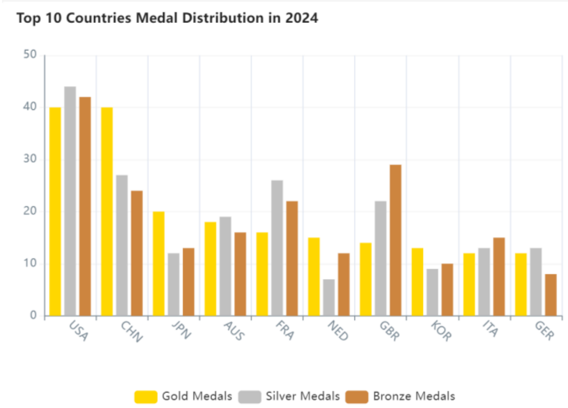
(a) Number of Summer Olympics Hosted by Continent



(b) Trend of Gold Medals Won by the United States Over the Years



(b) Comparison of Total Medals Won by Top 5 Countries Across Olympic Years



(d) Top 10 Countries Medal Distribution in 2024

Figure 3: Visualization analysis plots

4 Notations

Table 1: Important Notations used in this paper

Symbol	Description
$C_i^{(t_0)}$	Performance indicator of **country** i in athlete's Olympic debut year t_0.
$S_j^{(t_0)}$	Performance indicator of **sport**-specific j in athlete's Olympic debut year t_0.
$P_k^{(t)}$	Individual momentum of **athlete** k in year t
$M_k^{(t)}$	**Overall** medal-winning capability of athlete k in year t
$\Theta_k^{(t)}$	Standout **probability** of athlete k in year t
a_1, a_2, a_3	Weights to adjust country, sport-specific, and individual impacts, learnable

5 Fundamental Model for Predicting Results

To comprehensively evaluate athlete's overall performance and predict expectation for number of medals, we constructed a weighted summation model incorporating country performance indicator C, sport-specific performance indicator S, and athlete's individual momentum P. Subsequently, the athlete's standout probability is calculated using the *softmax* function, and gold, silver, and bronze medals are allocated based on medals available for specific sport.

❖ **Country Performance Indicator** $C_i^{(t_0)}$

Calculated based on the exponential moving averages of the nation's historical and current performance.

Established during the athlete's Olympic debut year t_0 and remains fixed thereafter, reflecting the enduring influence of national factors.

❖ **Sport-specific Performance Indicator** $S_j^{(t_0)}$

Calculated based on the exponential moving averages of the nation's historical and current performance in a specific sport.

Established during the athlete's Olympic debut year t_0 and remains fixed thereafter, reflecting the enduring influence of sport-specific capabilities for certain country.

❖ **Individual Momentum** $P_k^{(t)}$

Determined by the athlete's historical performance, host nation status, and other factors, reflecting trends of improvement or decline, increasing as momentum.

Standardized to ensure fairness among athletes with differing participation frequencies.

❖ **Overall Medal-winning Capability** $M_k^{(t)}$

The Overall medal-winning capability $M_k^{(t)}$ for athlete k in year t is defined as:

$$M_k^{(t)} = a_1 \cdot C_i^{(t_0)} + a_2 \cdot S_j^{(t_0)} + a_3 \cdot P_k^{(t)} \tag{1}$$

The coefficients a_1, a_2, and a_3 are trainable parameters that adjust the contributions of the country, sport-specific performance and individual momentum to overall medal-winning ability. By combining these components, the model provides a robust method for evaluating an athlete's overall performance while ensuring adaptability and fairness across events and individual circumstances.

Fig. 4 serves as a conceptual model diagram for this model.

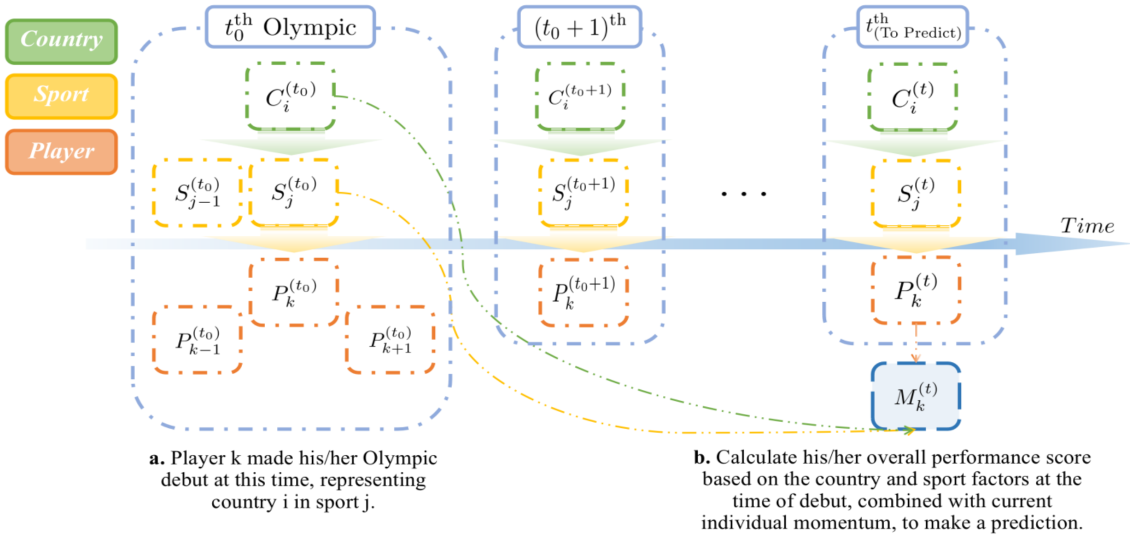


Figure 4 : Conceptual Model Diagram

5.1 Details of Country Performance Indicator

Table 2: Description of Variables Related to Country Performance Indicator

Variables	Description
$C_i^{(t)}$	Country performance indicator of country i in year t
$c_i^{(t)}$	Country performance indicator with NO historical information
$\beta_0, \beta_1, \beta_2, \beta_3$	Trainable parameters
Gold, Silver, Bronze	Number of medals won by the country that year
N	Number of athletes from the country that year

We define the **Country Performance Indicator** $c_i^{(t)}$ of country i in year t with **NO** historical information as:

$$c_i^{(t)} = \frac{1}{1+\beta_0 N}\left[\beta_1 \cdot Gold + \beta_2 \cdot Silver + \beta_3 \cdot Bronze + 1\right] \tag{2}$$

where $\beta_0, \beta_1, \beta_2, \beta_3$ are trainable parameters used to adjust the contributions of gold, silver, and bronze medals, as well as the number of participants.

To incorporate the historical performance of the country, we use the exponential moving average method to update the **Country Performance Indicator** $C_i^{(t)}$:

$$C_i^{(t)} = a^{(t)} \cdot c_i^{(t)} + (1-a^{(t)})C_i^{(t-1)} \tag{3}$$

Where $a^{(t)}$ is the weight coefficient for year t, defined as:

$$a^{(t)} = \frac{2}{t+1}, t \geq 1 \tag{4}$$

Explanation: The Country Performance Indicator serves as a snapshot of a country's long-term success, integrating both historical and current performances. Using an exponential moving average method, it dynamically adjusts the weight of historical results, ensuring the index remains responsive to recent trends while acknowledging the legacy of past achievements.

5.2 Details of Sport-specific Performance Indicator

Similar to the Country Performance Indicator, we introduce an indicator that evaluates a country's performance in specific sport events, referred to as the Sport-specific Performance Indicator. The calculation is highly similar to that of the Country Performance Indicator, but differs in parameters.

Table 3: Description of Variables Related to Sport-specific Performance Indicator

Variables	Description
$S_j^{(t)}$	Sport-specific Performance Indicator of sport *j* in year *t* (specific to countries)
$s_j^{(t)}$	Sport-specific Performance Indicator with NO historical information
$\gamma_0, \gamma_1, \gamma_2, \gamma_3$	Trainable parameters
Gold, Silver, Bronze	Number of sport-specific medals won by the country that year
N	Number of the country's sport-specific participants that year

We define the **Sport-specific Performance Indicator** $s_j^{(t)}$ of sport *j* in year *t* with **NO** historical information as:

$$s_j^{(t)} = \frac{1}{1+\gamma_0 N}\left[\gamma_1 \cdot Gold + \gamma_2 \cdot Silver + \gamma_3 \cdot Bronze + 1\right] \tag{5}$$

where $\gamma_0, \gamma_1, \gamma_2, \gamma_3$ are trainable parameters used to adjust the contributions of gold, silver, and bronze medals, as well as the number of participants.

Similar to Country Performance Indicator, the **Sport-specific Performance Indicator**, $S_j^{(t)}$,is updated using the exponential moving average:

$$S_j^{(t)} = a^{(t)} \cdot s_j^{(t)} + (1-a^{(t)})S_i^{(t-1)} \tag{6}$$

Where $a^{(t)}$ is the weight coefficient for year *t*, defined in the same way as in Country Performance Indicator.

Explanation: The Country and Sport-specific Performance Indicators share a similar framework, both using weighted summation and exponential moving average methods, with the weight coefficient $a^{(t)}$ calculated identically to balance current and historical performance. However, they differ in parameters — $\gamma_0, \gamma_1, \gamma_2, \gamma_3$ for event-specific evaluation and $\beta_0, \beta_1, \beta_2, \beta_3$ for overall performance — and in scope, as Sport-specific Performance Indicator focuses on specific sport, while Country Performance Indicators assesses overall performance across all events.

5.3 Details for Individual Momentum

To measure the progression or regression trends of athletes, we introduce the concept of Individual Momentum. Individual Momentum is determined by factors such as historical performance and host status, increasing as time progresses, and is standardized after each Olympic to ensure fair comparisons between athletes with different participation frequencies.

Table 4: Description of Variables Related to Individual Momentum

Variables	Description
$P_k^{(t)}$	The standardized momentum of athlete k in year t
$P_k'^{(t)}$	The momentum of athlete k in year t with NO standardization
$\eta_1, \eta_2, \eta_3, \eta_4, \eta_5$	Trainable parameters
Gold, Silver, Bronze	Number of medals won by the athlete that year
No Medal	Number of events athlete won no medal that year
Host	Host status (1 if the athlete's country is the host, 0 otherwise).

The **Individual Momentum** of athlete k in year t with **NO** standardization, $P_k'^{(t)}$, is defined as:

$$P_k'^{(t)} = P_k'^{(t-1)} + \eta_1 \cdot Gold + \eta_2 \cdot Silver + \eta_3 \cdot Bronze + \eta_4 \cdot NoMedal + \eta_5 \cdot Host \tag{6}$$

where $P_k'^{(t-1)}$ represents the momentum of athlete k in the previous year, with an initial value of *0* for athletes without historical performance.

To address the issue that momentum has no clear upper boundary — where athletes with frequent participation might accumulate higher momentum values, creating an unfair advantage over new participants — momentum is standardized as follows:

$$P_k^{(t)} = \frac{P_k'^{(t)} - \mu^{(t)}}{\sigma^{(t)}} \tag{7}$$

The standardized Individual Momentum $P_k^{(t)}$ follows a distribution with a mean of 0 and a standard deviation of 1, eliminating bias caused by variance in participation frequency.

Explanation: Individual Momentum captures an athlete's performance trends, reflecting progression or regression, and the influence of host status. Standardization ensures comparability across athletes with varying participation frequencies. Dynamic updates reflect real-time momentum changes, providing a fair and adaptive evaluation framework.

5.4 Winning Probability Calculation

The Overall Medal-winning Capability of athletes $M_k^{(t)}$ is converted into their standout probabilities $\Theta_k^{(t)}$ using the *softmax* function. This transformation ensures that the probabilities are normalized and reflect the relative performance of athletes within the context of the competition.

$$\Theta_i^t = \frac{e^{M_i^{(t)}}}{\sum_{j=1}^{N} e^{M_i^{(t)}}} \tag{5}$$

5.5 Medal Allocation

Medals—gold, silver, and bronze—are distributed based on the winning probabilities and the total number of medals available for events of sport.

Gold Medal Allocation:

$$Gold_i = \min(1, \Theta_i^{(t)} \cdot TotalGold) \tag{6}$$

Silver Medal Allocation:

$$Silver_i = \min\left(1, \Theta_i^{(t)} \cdot (TotalGold + TotalSilver)\right) - Gold_i \tag{7}$$

Bronze Medal Allocation:

$$\mathrm{Bronze}_i = \min\left(1, \Theta_i^{(t)} \cdot TotalM\mathrm{edal}\right) - Gold_i - Silver_i \tag{8}$$

To ensure authenticity and efficiency in medal allocation, a two-step optimization process is applied. Firstly, for athletes participating in multiple sub-events, their winning probabilities are evenly distributed across all events they compete in. Secondly, athletes with higher winning probabilities are prioritized. Medals are initially distributed based on their expected counts, and the remaining medals are reallocated to others. After each allocation, the probabilities of the remaining athletes are normalized again, and this process continues iteratively until all medals are distributed.

5.6 Model Training

The model is trained using data from 2024 and earlier, optimized iteratively through gradient descent using AdamW optimizer. The learning rate is set to 0.1, weight decay to 0.0005, and batch size to 1. Each epoch consists of 29 iterations, and the training process runs for a total of 100 epochs.

6 Solution for Question I

6.1 Projections for the Medal Table in 2028

6.1.1 2028 Medal Table and Prediction Intervals from the Result

We first use our model for model prediction, then we follow the following procedure to estimate the prediction intervals:

- Firstly, we utilize the relationship between the predicted values and actual values in the training set to fitting the medal count and its error: $\hat{e}^2 = g(x)$. Here we assume e2 is linearly related to the number of medals.
- Then we combine the degrees of freedom adjustment to estimate the variance function:

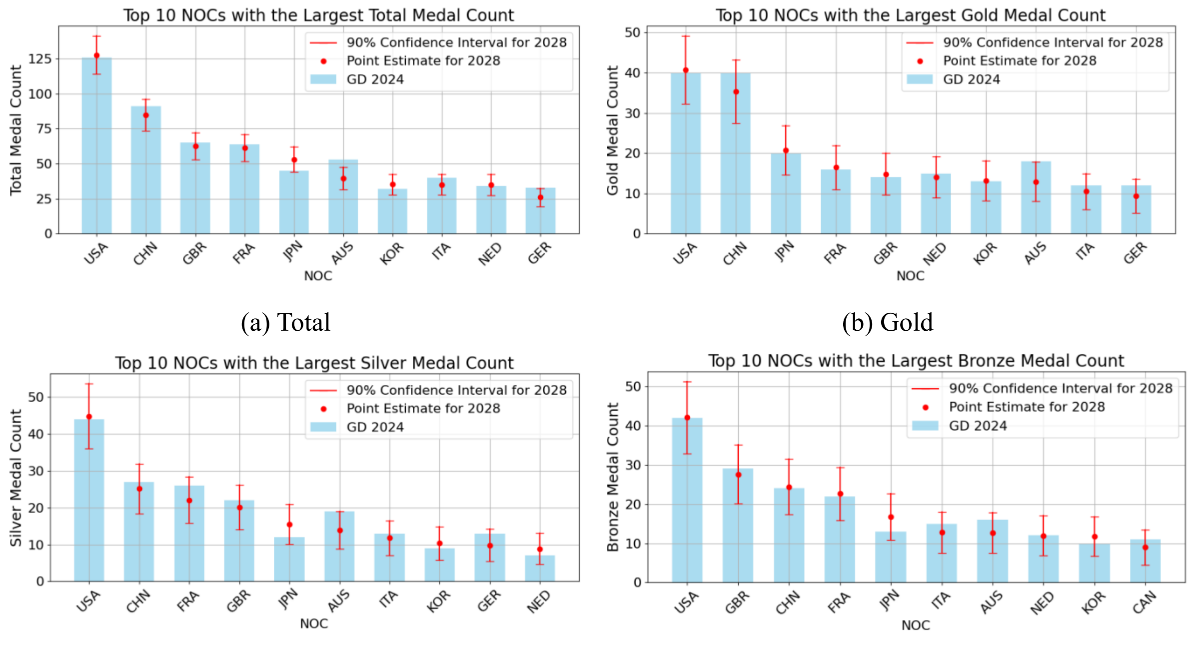
$\hat{\sigma}^2 = \dfrac{n}{n-p} g(x)$,where n is the total sample size, and p is the number of parameters.

- The prediction interval is given by: $\hat{y} \pm t_{a/2}(v)\hat{\sigma}_{pred}$, with $v = n - p = 29 - 16 = 13$. Here, $t_{a/2}$ represents the critical value from the t-distribution.

The fitting results between medal counts and errors, based on the predicted and actual values from the training set, are as follows:

- Gold Medals Fit: $y = 0.285\mathrm{x}^0 + 0.242\mathrm{x}^{1}$
- Silver Medals Fit: $y = 0.404\mathrm{x}^0 + 0.241\mathrm{x}^{1}$
- Bronze Medals Fit: $y = 0.373\mathrm{x}^0 + 0.276\mathrm{x}^{1}$
- Total Medals Fit: $y = 0.726\mathrm{x}^0 + 0.203\mathrm{x}^{1}$

These fitting results indicate the relationship between medal counts and prediction errors, with x^0 representing the constant term and x^1 representing the linear term.



(a) Total (b) Gold

(c) Silver (d) Bronze

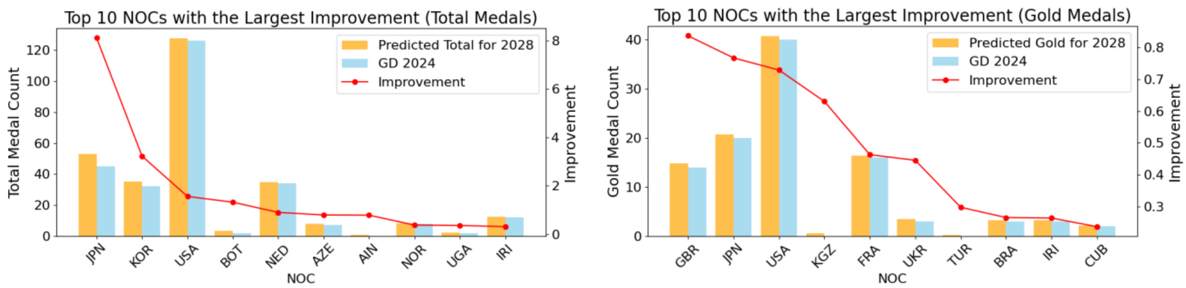
Figure 5: Medal Table Prediction and Intervals for the 2028 Los Angeles Olympics

As shown in Fig. 5, the United States is projected to maintain a significant advantage in total medal count at the 2028 Los Angeles Olympics, securing the top position. This dominance is primarily attributed to its status as the host nation, demonstrating a pronounced home-field advantage. As shown in the figure, the point estimate for the U.S. exceeds 120 medals, with a wide 90% confidence interval, reflecting its substantial potential for medal acquisition. China is expected to rank second; however, its predicted total medal count shows a noticeable decline compared to its actual performance in 2024. Japan and South Korea are both projected to experience upward trends in their medal counts. Prediction for Japan shows a significant improvement from its 2024 ground truth (GD), while South Korea's medal count is slightly enhanced, with a point estimate approaching 40 medals. France, as the 2024 host nation, is predicted to witness a slight decrease in medal count in 2028 compared to its GD in 2024, likely due to the diminished impact of home-field advantage.

In terms of gold medals, the U.S. is expected to maintain a clear lead, with a point estimate near 40 and a wide confidence interval, indicating its strong competitiveness across multiple premier events. Conversely, China' s gold medal count is projected to decline significantly, falling below its GD value from 2024.

6.1.2 Improvement or Regression

Based on our model, the projections for the 2028 Los Angeles Summer Olympics medal table show the following trends for improvement (Fig. 6):



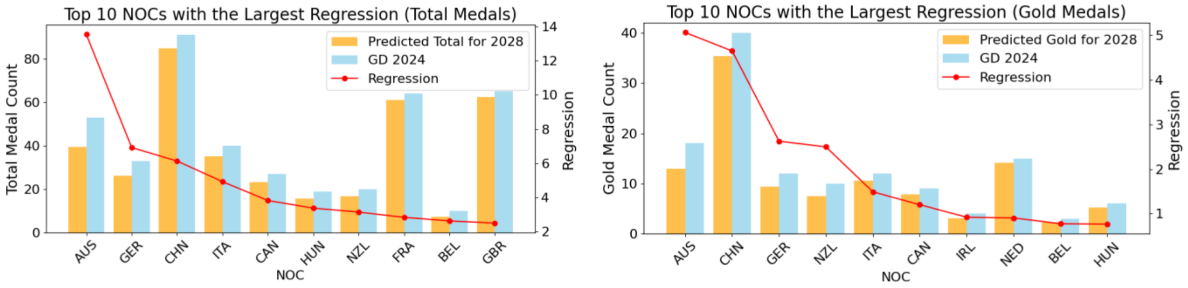
(a) Total (b) Gold

Figure 6: Top 10 NOCs with largest improvement

As shown, Japan (JPN) leads in the total medal count improvement. Japan's predicted total for 2028 shows a sharp increase compared to its GD (Ground Truth) in 2024, making it the top improver among all NOCs. South Korea (KOR) follows with a significant predicted gain in total medals, reflecting a growing competitiveness across multiple events. The United States (USA), despite already being a dominant force, is predicted to exhibit further improvement in its total medal count, attributed to its home advantage. Other nations, such as Botswana (BOT), Azerbaijan (AZE), and the Netherlands (NED), show smaller but notable improvements, indicating progress in targeted sports. On the lower end, nations like Iran (IRI) and Uganda (UGA) display modest gains.

As for gold medals, Great Britain (GBR) and Japan (JPN) exhibit the most notable improvements, with JPN leveraging its strengths in key events. The USA also demonstrates a steady increase in its gold medal tally, maintaining its dominance. Other nations like Kyrgyzstan (KGZ), Ukraine (UKR), and France (FRA) are expected to see moderate improvements. Nations such as Brazil (BRA), Iran (IRI) and Cuba (CUB), while on the list of improvers, are projected to see relatively minor increases in gold medals.

Meanwhile, our model also delves into the projected regressions among certain countries (Fig. 7):



(a) Total (b) Gold

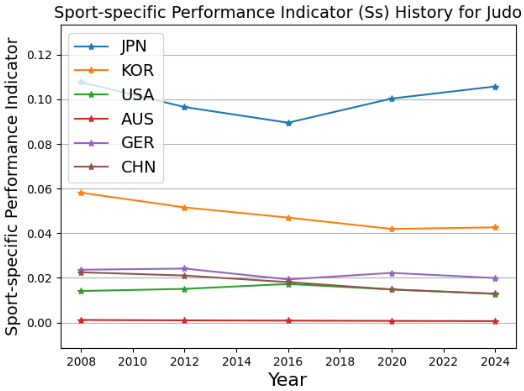
Figure 7: Top 10 NOCs with largest regression

Australia (AUS) exhibits the most significant regression in total medal count. The predicted total medals for 2028 shows a sharp decline compared to its GD (Ground Truth) in 2024, highlighting potential challenges in maintaining its previous performance levels across various events. Similarly, Germany (GER) and China (CHN) follow with substantial predicted decreases in their total medal counts, signaling possible declines in competitiveness in their key sports. Italy (ITA) also shows a noticeable decline, with a predicted medal count notably below its 2024 GD. Other countries, including Canada (CAN), Hungary (HUN), and New Zealand (NZL), exhibit moderate regression, reflecting potential struggles in retaining their recent medal performances. France (FRA) and Belgium (BEL), while maintaining relatively stable medal counts, show minor declines, possibly indicating reduced success in specific events.

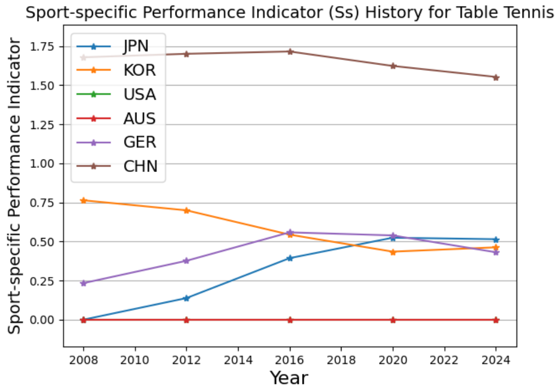
For gold medals, Australia (AUS) and China (CHN) again lead the regression trends, with significant decreases predicted for 2028 compared to 2024 GD values. Germany (GER) and New Zealand (NZL) follow, showing moderate reductions in gold medal predictions. Italy (ITA) and Canada (CAN) also reflect downward trends, albeit less pronounced. Other nations such as Ireland (IRL), Belgium (BEL), and Hungary (HUN) exhibit relatively minor declines in gold medal counts, suggesting challenges in sustaining top performances in their respective areas of strength.

6.1.3 Trend for specific countries of certain sports

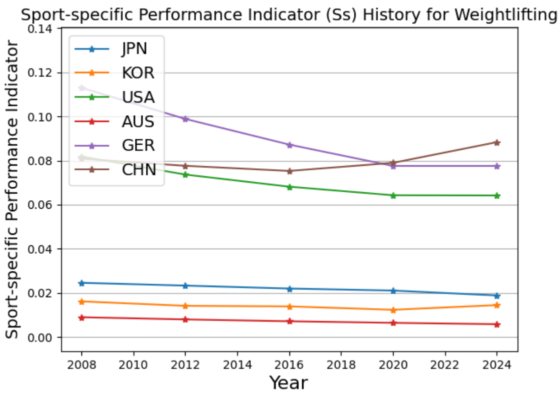
To investigate the factors influencing the changes in medal count, we selected the top three improving countries (JPN, KOR, USA) and the top three declining countries (AUS, GER, CHN). The sport-specific performance trends in certain dominant sports for these countries are illustrated in the Fig. 8:



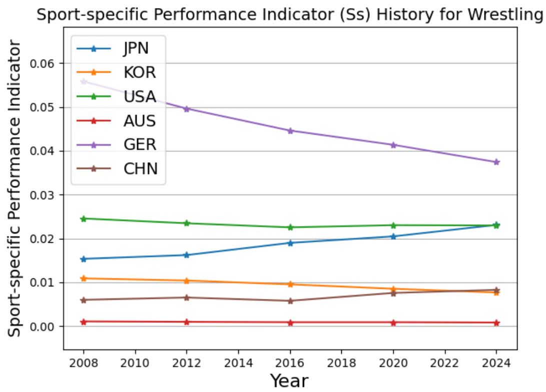
(a) Judo



(b) Table Tennis



(c) Weightlifting



(d) Wrestling

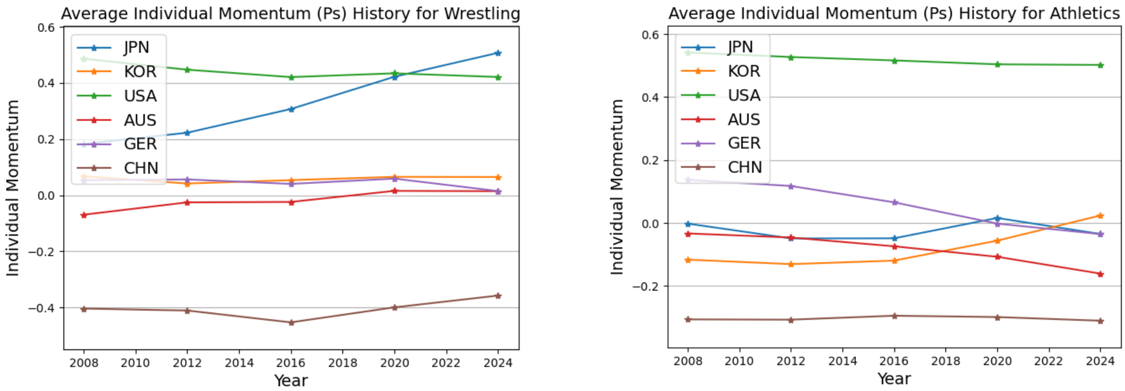
Figure 8: Sport-specific Performance Indicator History for various sports

For Judo, Japan demonstrates a strong performance in this event, maintaining high Sport-specific Performance Indicator values throughout the period. Notably, from 2016 onwards, the Sport-specific Performance Indicator show a rapid increase, indicating Japan's enhanced competitiveness and dominance in this domain. This upward trend underscores the country's strategic focus on Judo.

Korea also demonstrates positive trends across major events. In Wrestling, the Sport-specific Performance Indicator shows a slight upward trend over the years, indicating improved performance in this event. In Weightlifting, the Sport-specific Performance Indicator remain relatively stable but exhibit minor improvements in recent years. These trends provide evidence supporting Korea's potential medal growth.

On the other hand, China, despite maintaining dominance in Table Tennis, shows a gradual decline in Sport-specific Performance Indicator from 2016 to 2024. This decline indicates a reduction in overall performance in this event, even though the values remain significantly higher than those of other countries. Although China's Sport-specific Performance Indicator in weightlifting has increased, this does not significantly contribute to its medal table ranking since the number of weightlifting events has been reduced by 1/3 from 2016 to 2024.

Meanwhile, Germany's Sport-specific Performance Indicator in Weightlifting and Wrestling show a consistent decline from 2008 to 2024. This downward trend reflects a weakening competitiveness in these historically strong events.



(a) Wrestling (b) Athletics

Figure 9: Average Individual Momentum History for various sports

We also visualize Individual Momentum for several sports, as shown in Fig. 9. In Wrestling, Japan and the United States consistently maintain high momentum values, with Japan showing a steady increase in Individual Momentum over the years. Conversely, Germany exhibits a declining trend in recent years, indicating weakened performance in this event.

In Athletics, the United States maintains a dominant advantage, as reflected by consistently high Individual Momentum throughout the observed period. Korea demonstrates a gradual upward trend in Individual Momentum, suggesting ongoing improvements in this event. In contrast, Germany and Australia show a downward trajectory, indicating declining competitiveness. Meanwhile, China remains at consistently low Individual Momentum, reflecting minimal progress or influence in this event.

6.2 First Medal Predictions

We evaluated the likelihood of athletes or nations earning their first medal in the next Olympics, focusing on the factors that may contribute to such breakthroughs. Through this analysis, we identified the following projections (Fig. 10):

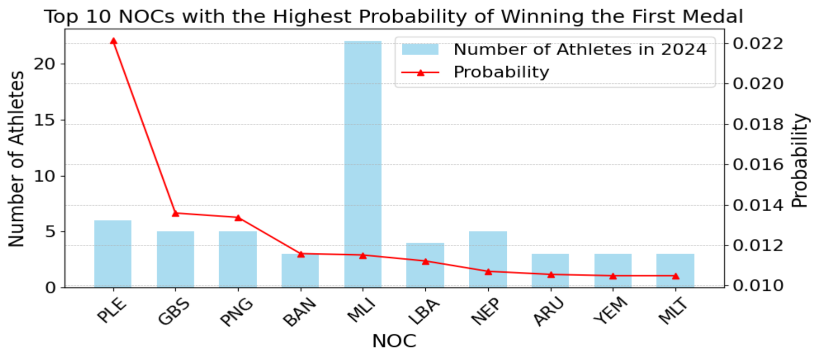
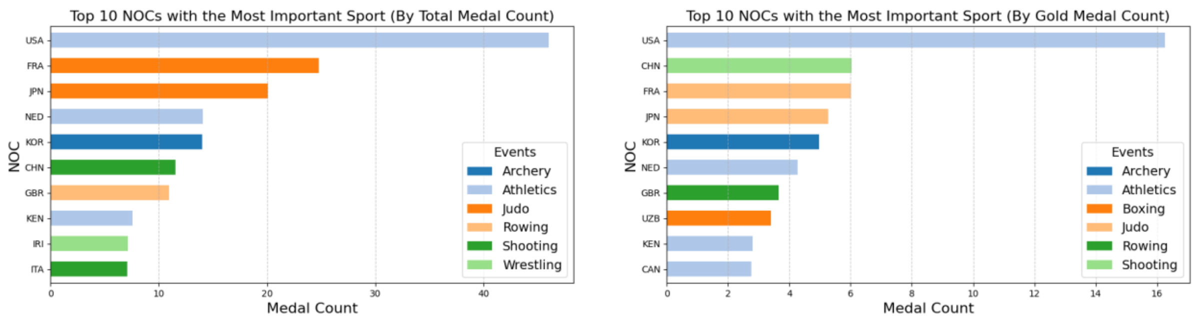


Figure 10: First medal probability for Top 10 NOCs

Palestine (PLE) emerges as the leader, demonstrating the highest probability (0.022) of success despite a relatively small contingent of athletes. In contrast, Mali (MLI) stands out with a significantly larger number of athletes but only a moderate probability of achieving this milestone(lower than 0.012). Guinea-Bissau (GBS) and Papua New Guinea (PNG) follow closely, each with approximately five athletes and a relatively high likelihood of success(0.012~0.014). Other countries, such as Bangladesh (BAN), Nepal (NEP), Libya (LBA), and Mali (MLI), show moderate chances of earning their first medal. Meanwhile, Aruba (ARU), Yemen (YEM), and Malta (MLT) have smaller delegations and comparatively lower probabilities relative to the top-ranked Palestine. However, for all these nations, the chances of earning their first medal remain limited overall.

6.3 Impact of the Number and Types of Events on Medal Distribution

6.3.1 Important Sports and Reasons



(a) Total (b) Gold

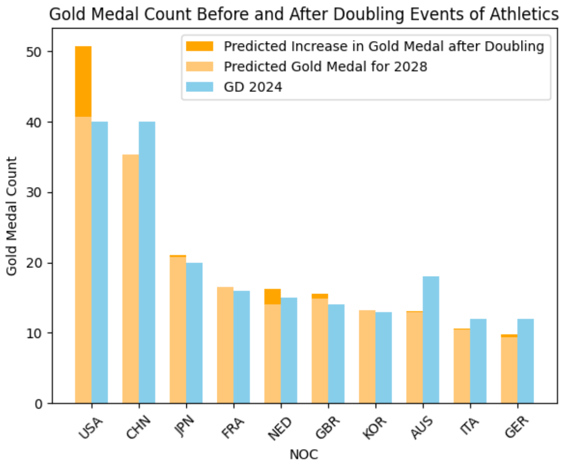
Figure 11: Most important Sport for Top 10 NOCs

First, we identified the dominant sports by analyzing the medal counts across various sports for each country, as illustrated in Fig. 11.

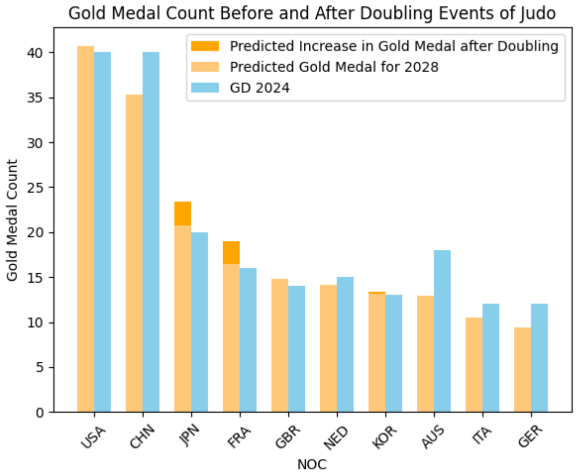
Chart (a) presents the events where each country achieves the highest total medal counts. For example, the USA stands out in Archery with the highest overall medal tally, while France excels in Athletics and Japan in Judo. Korea and the Netherlands show strength in Rowing, and China performs particularly well in Shooting.

Chart (b) zooms in on gold medals, highlighting the events that most significantly contribute to each National Olympic Committee's (NOC) success. The USA continues to dominate Archery with the highest number of gold medals, while China leads in Shooting. France and Japan also perform strongly in Athletics and Judo, respectively, in terms of golds. Notably, Uzbekistan appears in Boxing, underlining its significance in contributing to their overall success.

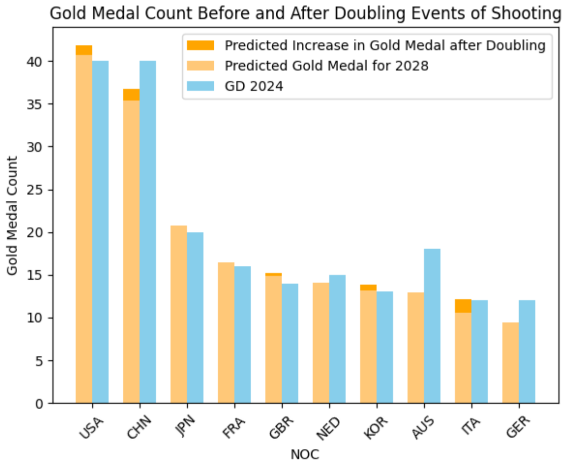
6.3.2 Choice of Events



(a) Athletic



(b) Judo



(c) Shooting

Figure 12: Predicted Modals Before and After Doubling Events

Then, we analyzed the potential impact of doubling the number of events in different sports, particularly focusing on how the host country's event selection might influence medal outcomes. The key findings from this analysis are as follows:

For athletics, doubling the number of events led to a significant increase in the gold medal count for the United States, highlighting its dominance in this sport. The Netherlands, the United Kingdom, and Germany also saw slight increases in their gold medal counts, while other countries showed little to no change. If the United States were the host nation, expanding athletics events could further solidify its position at the top of the medal table.

In the case of judo, the data revealed moderate increases in gold medals for Japan and France, indicating their competitive strength in this discipline. On the other hand, the United States and China saw little change in their gold medal tallies, and there were no significant improvements for Australia, Italy, or other nations. Should Japan or France host the games, increasing the number of judo events could strategically boost their medal counts even further.

For shooting, doubling the number of events reinforced the dominance of the United States and China, both maintaining substantial leads in gold medal counts. The United Kingdom, South Korea, and Italy experienced modest gains in their medal totals, while other nations' results remained stable. Any host nation aiming to strengthen its position on the medal table might consider increasing the number of shooting events as a viable strategy.

Additionally, we considered the increase in the number of Weightlifting events from 10 to 15, reverting to the 2016 level. This increase directly impacts China's total gold medal count, which rises from 3 to 5, reflecting an absolute gain of 2 gold medals. This outcome further demonstrates that the addition of key events significantly boosts the total gold medal tally.

7 Solution for Question II

7.1 Estimate of "Great Coach" Effect

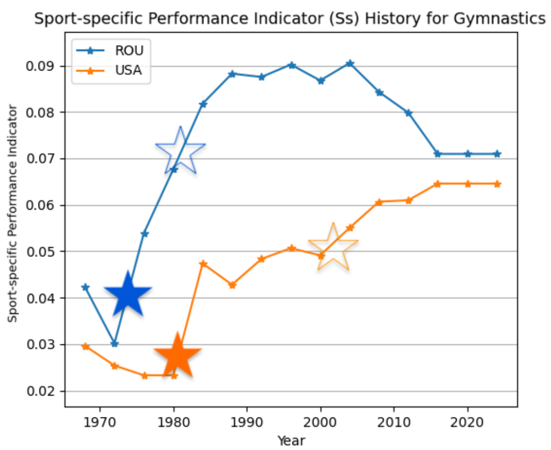


Figure 13: Sport-specific Performance Indicator History for Gymnastics

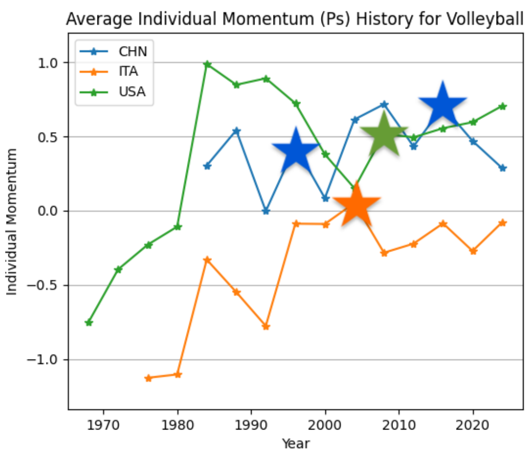


Figure 14: Average Individual Momentum History for Volleyball

Long-term effects of great coaches:

It can be observed that the long-term trend is mainly reflected by Sport-specific Performance Indicator, which shows a steady upward trajectory with minimal short-term fluctuations. For instance, as shown in the Fig. 13 (solid stars indicate the start of a coaching tenure, while hollow stars mark its end), during Béla Károlyi's coaching tenure in Romania (1970s to 1981), Sport-specific Performance Indicator increased from 0.0302 to 0.0676, an improvement of 0.0374, averaging an increase of 0.0187 per season. In the United States (1981 to 2001), Sport-specific Performance Indicator rose from 0.0233 to 0.0491, a total increase of 0.0258, averaging 0.0052 per season.

Short-term effects of great coaches:

The short-term momentum is captured by Average Individual Momentum, which exhibits significant fluctuations. For example, in Fig. 14 (solid stars represent Olympic Games participated in during the coaching tenure), Lang Ping's coaching periods in China (1995 – 1999 and 2013 – 2021) showed increases from -0.0034 to 0.4350 and from 0.4322 to 0.7020, with total increases of 0.4384 and 0.2693, respectively. During her tenure in the United States, Average Individual Momentum rose from 0.1503 to 0.5174, an increase of 0.3671. In her earlier coaching years in Italy, average Individual Momentum increased from -0.0901 to 0.0513, a total rise of 0.1414.

7.2 Investing In A "Great" Coach

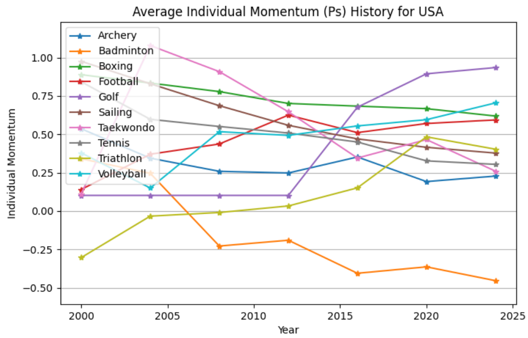


Figure 15: Average Individual Momentum History for USA

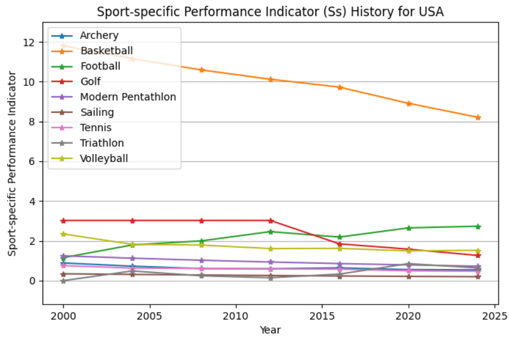


Figure 16: Sport-specific Performance Indicator History for USA

Table 5: USA Investing Suggestions

Short term	
Sport	**Individual Momentum Trend Analysis**
Taekwondo	Significant decline since 2004, Ps dropped from above 1 to around 0.25 by 2024
Sailing	Steady decline since 2000, Ps dropped to below 0.5 by 2024
Badminton	Noticeable decline since 2000, Ps dropped to near -0.5 by 2024
Boxing	Gradual decline since 2000, Ps dropped from above 0.75 to around 0.5 by 2024
Long term	
Sport	**Event Performance IndexAnalysis**
Basketball	Noticeable decline since 2000, Ss dropped from around 12.0 to 8.0 by 2024
Golf	Steady decline after 2012, Ss dropped from 3 to around 1 by 2024
Volleyball	Gradual decline after 2000, Ss dropped below 2.0 by 2024

Based on the analysis of Tab.5, it can be concluded that Taekwondo, Sailing, Badminton, and Boxing are experiencing significant short-term declines. These sports require the recruitment of highly skilled coaches to address immediate technical issues, enhance athlete performance, and refine competitive strategies.

On the other hand, Basketball, Golf, and Volleyball show more pronounced long-term declines, indicating the necessity for strategic investment in exceptional coaching to rebuild core skills, optimize tactical approaches, and ensure continuous development over the long term.

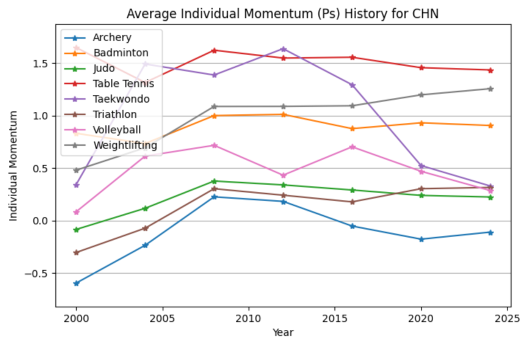


Figure 17: Average Individual Momentum History for CHN

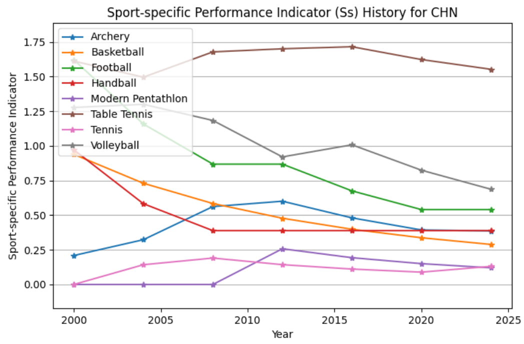


Figure 18: Sport-specific Performance Indicator History for CHN

Table 6: CHN Investing Suggestions

Short term	
Sport	**Individual Momentum Trend Analysis**
Archery	Reached its peak in 2008, followed by a decline, approaching -0.1 in 2024
Taekwondo	Rapid decline after 2012, dropping from 1.6 to around 0.3 in 2024
Volleyball	Significant decline after 2016, approaching 0.3 in 2024
Long term	
Sport	**Event Performance IndexAnalysis**
Archery	Continued decline after 2012, approaching 0.5 by 2024
Basketball	Gradual decline after 2012, falling below 0.5
Football	Persistently low performance, no significant improvement
Volleyball	Noticeable decline after 2016, approaching 0.2 by 2024

The analysis of Fig.17, 18 clearly indicates that both Archery and Volleyball are experiencing consistent declines in both the short term and long term. As such, prioritizing investment in "Great Coaches" for these two sports is essential to improve performance and reverse the ongoing downward trend.

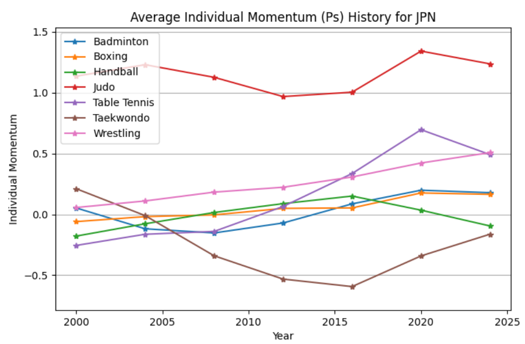


Figure 19: Average Individual Momentum History for JPN

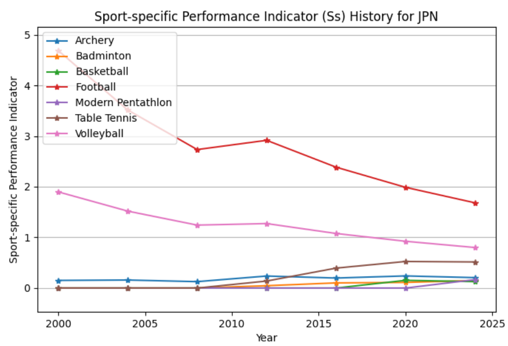


Figure 20: Sport-specific Performance Indicator History for JPN

Table 7: JPN Investing Suggestions

Short term	
Sport	**Individual Momentum Trend Analysis**
Handball	Gradual decline since 2016, Ps dropped steadily to near 0.0 by 2024

Long term	
Sport	**Event Performance IndexAnalysis**
Football	Significant decline after 2000, Ss dropped from 5.0 to around 2.0 by 2024
Volleyball	Noticeable decline after 2012, Ss approaching 0.8 by 2024

Fig. 19, 20 reveal that handball is experiencing a significant decline, requiring the recruitment of a highly skilled coach to address urgent tactical challenges and improve team dynamics. In contrast, both football and volleyball exhibit notable long-term declines, highlighting the need for strategic investment in exceptional coaches to rebuild foundational skills, refine game strategies, and ensure continuous development over time.

8 Solution for Question III

8.1 The Influence of Event Selection on Medal Distribution

Our model underscores the importance of event selection in determining a country's medal count. The number and types of events directly influence medal distribution, with countries that excel in resource-intensive sports, such as athletics, weightlifting, and shooting, benefiting from the expansion of these events. By increasing the number of events in these disciplines, countries can increase their medal opportunities, particularly in countries that have already demonstrated excellence in these sports.

Application of the Model: We use our model to evaluate how different countries might perform if certain sports or events were expanded or introduced. The model predicts that adding more events in key sports could benefit countries that already dominate these areas, while smaller nations might benefit from the introduction of new sports with lower investment requirements.

Recommendations for Olympic Committees:

- Committees should advocate for the addition of events in sports where their athletes have a historical advantage, thus increasing medal opportunities.
- For resource-limited nations, the introduction of new, low-investment sports—such as surfing or skateboarding—can provide more avenues for medal acquisition.

8.2 The Impact of Emerging Sports and Global Trends on Medal Distribution

Our model illustrates how emerging sports and global trends can influence the balance of medal distribution. New sports such as skateboarding, surfing, and rock climbing create opportunities for countries to secure medals in disciplines that require less historical investment or infrastructure compared to traditional Olympic events.

Application of the Model: Our model predicts that the inclusion of emerging sports could provide a competitive edge for countries with natural advantages in these areas, especially where fewer resources are required for training and competition. By embracing these sports, countries may have a better chance of securing medals without the high costs typically associated with traditional Olympic events.

Implications for Olympic Committees:

- Committees in nations with limited resources or historically weaker Olympic performances should focus on emerging sports where their athletes have a natural advantage, or where the barriers to entry are lower.
- This strategy can maximize medal opportunities in sports that may not yet be dominated by traditional Olympic powerhouses, providing countries with a unique competitive advantage.

9 Strengths and Weaknesses

9.1 Strengths

✓ The model uses exponential moving averages to integrate historical and real-time data, ensuring accuracy and reflecting both short-term trends and long-term performance.

✓ By combining national performance, event-specific indices, and athlete momentum, the model provides a comprehensive and balanced evaluation framework, supporting both individual and collective medal predictions.

✓ The use of indices like Ss (Event Performance Index) and Ps (Individual Momentum) captures fluctuations in performance, allowing tailored strategies for nations, events, and athletes.

✓ The model's results are presented intuitively with clear visual outputs (e.g., medal prediction charts), aiding decision-making for stakeholders.

9.2 Weaknesses

✓ The model is optimized for Olympic sports and requires adjustments to parameters and evaluation criteria when applied to other contexts or multi-sport events.

✓ Predictions for smaller delegations or emerging nations might suffer from reduced accuracy due to limited historical data.

✓ The reliance on past Olympic cycles as training data risks overlooking novel factors (e.g., new athletes or events) influencing outcomes in future games.

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