Hard Problems: Young Math Talents in the U.S. and Their Choices of Higher Education

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1 Introduction

Math competitions among the youth are regarded as a selection of talents in the early stage, which makes use of challenging mathematics questions to check whether the participants could deeply master the advanced knowledge. The awardees of these competitions are usually seen as students with beyond-the-average ability to work on hard problems and given by chances to more abundant research resources, for example, the students ranking at the top in The USA Mathematical Olympiad (USAMO for short) will be very likely to be admitted to prestigious institutions in the U.S. like Harvard, MIT, Princeton, etc. Many awardees of The William Lowell Putnam Mathematical Competition (Putnam for short) list their honors on CVs/Resumes also shows that the awards serve to be a pursuasive proof of their ability.

Could these math competitions effectively serve to select real young talents? And how the experience of receiving such honors affects their choices of career paths, especially the academic paths given their ability and education background? The questions are yet to be answered. In common sense, students who show their talents in high school or undergraduate will be given much attention and are encouraged to pursue higher degrees as well as create breakthroughs in science. The taste of early success could also build their self-belief in their academic capacity. However, on the other hand, the nationwide math competitions also shape the participants' beliefs by making some of them realize they are no longer the most talented one. Many students chose to participant the competitions with confidence of their ability comparing with their classmates, while not everyone of them would receive a satisfied results. For the students who got listed as Honorable Mention (HM for short) in USAMO, despite of having a chance to study mathematics at Harvard or MIT just as those gold medal winners, will they be less confident in being mathematicans? And for a student of Swarthmore who ranked in 20th place in Putnam, yet still the best performance in her or his college, will s/he be more confident than the former ones?

In this project, we manage to collect the education details after high school of the awardees in USAMO and Putnam between 1985 and 2010 to answer the above questions. By both manual collection and automatic matching, we build a dataset containing the awardees' choices of academic paths, such as whether having a doctorate degree, and if so, the fields of the degree.

We find that there exists an obvious gap between USAMO's gold medal and HM winners in their choices of major in undergraduate, graduate degrees, mathematics-related degrees, and whether to stay in the academia. Nearly half of these high school awardees chose to pursue a

doctorate degree in STEM or Economics, yet that of Putnam only results in less than 25%.

The paper adds to a series of discussions on the screening of young talents through special-designed challenges (Aghion et al., 2017; Agarwal and Gaule, 2020; Agarwal et al., 2023). Following the project on the awardees of the International Olympiad (Agarwal et al., 2024), the paper focuses on the math talents in the stage of high school and undergraduate in the U.S. (and Canada). These competitions are designed beyond the average difficulty in maths education in high school or college students, which guarantees us to confidently conclude that the participants, especially the awardees, are among the most talented young people in maths. The data collected in this paper generate similar conclusions that these young talents distinguished themselves in the competitions would show a stronger inclination to higher education and academia than the average.

The remaining of the paper is organized as follows. Section 2 introduces two competitions that are considered in the project; section 3 shows the data collection and process. Section 4 shows a few patterns we found based on the data, and section 5 concludes the paper.

2 USAMO and Putnam

2.1 USA Mathematical Olympiad

Starting in the year of 1972, USAMO is served as the final round of the American Mathematics Competitions to select top students into the United States National Team to compete in International Mathematical Olympiad (IMO). The competition lasts for nine hours with 6 questions in Number Theory, Geometry, Combinatorics, and Algebra respectively. Every year it invites around 500 eligible U.S. citizens or legal residents in the U.S. or Canada based on their performances in AMC competitions such as AMC 12 and AMC 10.

Before 2022, the 12 students with the highest rankings will be awarded with gold medals, and next approximately 12 performers will be listed in Honorable Mention lists. The top performers will then be invited to Mathematical Olympiad Program (MOP) for the further training and selection, among whom 6 National Team members will be chosen to represent the country in IMO.

Once get listed as an awardee of USAMO, no matter gold medal or HM winner, the student will receive opportunities to study at a high-ranking university. For example, among 121 awardees whose undergraduate placements could be searched, 27 students graduated from Harvard, 44 from MIT, 8 from CalTech, and 5 from Duke. For 39 students who never won gold medals and only got listed as HM, there are still 16 of them graduated from MIT, 3 from Harvard, and 4 from Princeton.

2.2 William Lowell Putnam Mathematical Competition

Putnam competition was founded in 1927 and then organized annually from 1938 by the Mathematical Association of America. Now it serves as one of the most important and famous math competitions among university students in the U.S. and Canada. The competition lasts for three hours and contains 12 questions that require specific knowledge and talents in mathematics. Any undergraduates at a participating college could enroll the competition as they wish, while the official team of the college is by selection. The top performers of Putnam will be awarded

with multi-level scholarship depending on their rankings. The top five teams win 25,000, 20,000, 15,000, 10,000, and 5,000 dollars respectively, and the individual awardees will be divided as the following levels: Top 5, Next 5, Next 6, Next 8, and Honorable Mention (HM for short).

Although a majority of the individual winners are undergraduates from prestigious universities famous for their maths departments, such as Harvard, MIT, CalTech, and Princeton, there are also students from small LACs and other schools, like Carleton College and St. Lawrence University. In this way, we could not only observe an individual's overall ranking among all the participants in the same year, but also her or his relative one within college.

3 Construction of Data

3.1 USAMO

We first collect a list of students of USAMO in the year of 1989, 1994-1998, and 2003-2010 who ranked top among the participants, including National Team members, the remaining Gold Awardees (top 6%), and Honorable Mentioned receivers (not winners and finished in the top 24). For each student, we record their times of winning the three honors respectively. We also keep the record of the year they first participated USAMO and got listed. The names of awardees after 2010 is available as well, but these observations are not very likely to obtain a Ph.D. degree before 2025.

Then we manually search and collect personal information of the names, including their undergraduate universities and majors, the highest degree they obtained, current positions and fields, and personal websites (either self-built websites or LinkedIn profiles) if exist. However, the work requires a large bulk of time and efforts. An example is given in Figure 1, where the awardee's public education and career information is collected from his personal website.

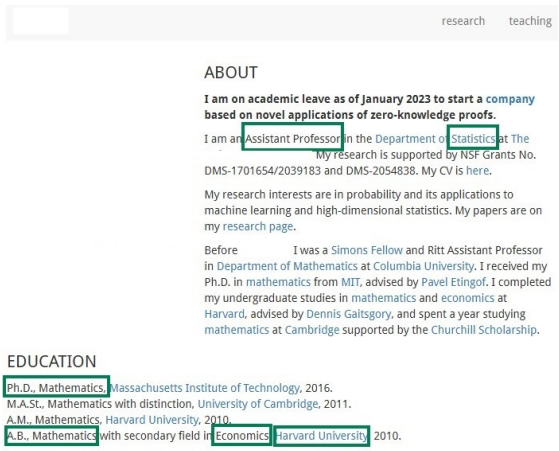
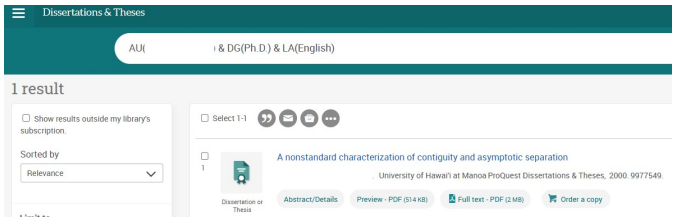


Figure 1: An example of manual information collection

Based on the list, we searched each of the names on ProQuest Dissertations & Theses database, one of the largest and comprehensive dissertation database. To make the process easier, we specify the searching strategy as "Author(name) & Degree(Ph.D.) & Language(English)",

that we focus on the dissertations written by the names in English to the application of a Ph.D. degree. Then for every search result, we scrape its Title, Author (this might be slightly different with the input of the names, because of fuzzy matching mechanism, and possible middle names and nicknames), Degree year, Subjects, Advisor, Institution, and Document URL. An example is shown in Figure 2.



(a) Search result of an awardee's name

Details

Subject	Mathematics; Statistics
Classification	0405: Mathematics 0463: Statistics
Identifier / keyword	Pure sciences; Asymptotic separation; Contiguity; Dichotomy; Nonstandard characterization
Title	A nonstandard characterization of contiguity and asymptotic separation
Author	
Number of pages	62
Degree date	2000
School code	0085
Source	DAI-B 61/07, Dissertation Abstracts International
ISBN	978-0-599-83455-2
Advisor	Ross, David A.
University/institution	University of Hawai'i at Manoa
University location	United States -- Hawaii
Degree	Ph.D.
Source type	Dissertation or Thesis
Language	English
Document type	Dissertation/Thesis

(b) Details of the dissertation result

Figure 2: An example of automatic information collection

Then we attempt to match the Ph.D. dissertations with the awardees, with the following rules:

- The difference of the year of an awardee partipating USAMO as a high school student and that of obtaining a Ph.D. degree should be more than 7 years;
- The subjects of the Ph.D. dissertations should be related to maths, applied maths, statistics, computer science, economics and social sciences. This is because in the process of data collection manually, we find the pattern that these awardees are very likely to choose these fields as their majors, both in undergraduate and graduate periods.

After the matching, there still exists a few cases that an awardee's name matches with multiple dissertations. For these cases, we manually search the awardee's information and match

her/him with the most appropriate results.

In this way, we manage to build a small dataset of 181 observations, including the award winners of USAMO between 1989 and 2010, with their undergraduate and graduate paths, as well as career choices. Comparing the two ways of data construction, the manual collection finds 94 Ph.D.s, while the automatic matching finds 87. Among 181 observations, 138 of them (76.24%)show the same result in both methods.

3.2 Putnam

The construction of Putnam data is following similar ways of USAMO dataset. However, there are two main differences. The first is that the list of Putnam awardees provides both their names and affiliations, which makes it easier to search their information online. However, the second is that the observations of Putnam awardees are much more than that of USAMO, so it will be very time consuming to manually collect the data. Currently, we only consider looking at the pattern of winning a Putnam award and the choice of pursuing a Doctor's degree.

We repeat the coarse scraping of the awardees' Ph.D. dissertations, and match them with the name list. The matching rule is the same as before, with the only difference is we narrow down the year difference of Putnam and Ph.D. degree to more than 5 years.

What we going to do the next is to successfully match the names with multiple dissertations, and construct variables describing the relative ranking of the participants in their universities.

4 Results

More than half of the USAMO awardees are matched with a record of Ph.D. dissertation in maths-related fields, while only 21.3% (192 out of 900 observations) of the Putnam awardees are matched. Among the USAMO awardees, the choices of academic paths among different awardees are also slightly different. Compared with those gold medalists, HMs are the least likely to pursue a graduate degree in maths and enter the academia even 47.67% of them selected math as their undergraduate major. Considering that there is a possible overlap between gold medalists and HMs, the difference could be even larger. The general result is shown in Figure 3.

		Selecting math as undergrad major		Obtaining a PhD		Obtaining a graduate degree in math		Being a professor after graduation	
	Count	Count	Ratio (%)	Count	Ratio (%)	Count	Ratio (%)	Count	Ratio (%)
IMO winners	75	40	53.33	47	62.67	39	52.00	30	40.00
USAMO gold medalists	139	66	47.48	91	65.47	65	46.76	51	36.69
USAMO gold medalists without IMO	64	26	40.62	44	68.75	26	40.63	21	32.81
HMs	86	41	47.67	40	46.51	16	18.6	23	26.74

Figure 3: Overall choices of higher education by different awardees in USAMO

The undergraduate university and doctorate university lists are also provided in Table 2 and Table 3 respectively. More than half of the awardees whose education background could be searched ended up obtaining a bachelor's degree from an Ivy League university, and the same pattern exists for their choice of a doctorate degree.

As for the Putnam awardees, the records indicate that the pattern of obtaining a doctorate degree from an Ivy League member still holds as shown in Table 4. However, only 192 out of 900 observations are matched with a result.

Table 1 presents an overview of the doctorate degree attainment choices among different groups of Putnam awardees. Similar to USAMO, higher-ranked awardees tend to pursue Ph.D. degrees at a slightly higher rate. Among the Top 5 finishers, 25.93% went on to obtain a Ph.D. And the rate is 27.39% for Top 6-16 group, and 30.92% for Top 17-25. Honorable Mention recipients have the lowest Ph.D. attainment rate. Considering that some participants would attend Putnam in different years and won different awards, the second part of the table also takes a full investigation to people who never got listed in Top 5, Top 16, and Top 25. Still, the top 25 awardees pursue a Ph.D. degree with similar rates of around 20%, while only 18/36% of the students who only won HM would obtain a doctorate degree.

Table 1: Overall choices of doctorate degrees by different awardees in Putnam

	Count	Ph.D. degree	Percentage
Top 5	81	21	25.93%
Rank 6-16	157	43	27.39%
Rank 17-25	152	47	30.92%
HM	657	131	19.94%
HM only	572	105	18.36%
Never rank Top 5	819	171	20.88%
Never rank Top 16	687	139	20.23%

5 Conclusion

The analysis of Putnam and USAMO awardees reveals a clear correlation between competition performance and long-term academic engagement. By building a unique dataset of the top awardees in the two mathematics competitions in the U.S., we predict that individuals who attain higher ranks in these prestigious competitions are more likely to pursue advanced degrees, particularly in mathematics. IMO winners and USAMO gold medalists exhibit the highest Ph.D. attainment rates, reinforcing the idea that early mathematical excellence translates into sustained academic ambition. Furthermore, the percentage of these awardees who go on to become professors highlights the role of competitive mathematics as a prediction for academic careers.

However, this trend is not absolute. While top-ranked competitors are more inclined to pursue Ph.D.s, a substantial fraction do not continue in academia. The lower Ph.D. attainment rates among Honorable Mention recipients and the even lower rates observed in Putnam awardees suggest that beyond competition success, external factors such as personal interest, career opportunities, and institutional influences play a crucial role in shaping long-term career paths. The mechanism behind the phenomenon is yet to be discovered.

There are lots of future facts to be checked. For example, a more detailed analysis of career outcomes beyond academia would be beneficial. Many talented mathematicians may opt for non-academic paths, and exploring their career choices could provide a better way to encourage scientific breakthroughs. Also, the role of peer pressure on these young talents' choices of academic paths also needs more attention, that whether the relative ranking within the same affiliation could shape the awardees' self beliefs, and hence force their willingness to become a scientist.

References

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Table 2: The distribution of undergraduate university of USAMO awardees

Undergraduate University	Number
Carnegie Mellon	3
Duke	6
Harvey Mudd College	1
Kansas State	1
Stanford	4
Swarthmore	1
WUSTL	1
Williams College	2
Yale	3
Caltech	8
Cornell	1
Florida State	1
Harvard	27
Maryland	1
Michigan	1
MIT	44
Princeton	8
Toronto	3
UIUC	1
Vanderbilt	1
Waterloo	1
Skipped	2
Total	121

Table 3: The distribution of doctorate university of USAMO awardees

University	Number
Arizona State	1
CalTech	1
Carnegie Mellon	1
Columbia	1
Cornell	1
Harvard	10
MIT	22
NUS	1
NYU	2
Ohio	1
Princeton	12
Rutgers	1
Stanford	11
Alabama	1
Chicago	3
UWM	2
UCB	11
Hawai'i	1
Kansas	1
Maryland	1
Virginia	1
Total	85

Table 4: The distribution of doctorate university of Putnam awardees

University	Number
Boston College	1
Brown	1
Budapest University of Technology	1
Carnegie Mellon	3
Columbia	2
Cornell	4
Dalhousie	1
Duke	1
Harvard	21
Illinois Institute of Technology	1
ICL	1
MIT	47
McGill	1
NYU	2
Oregon State	1
Princeton	25
Rice	1
Stanford	16
SUNY Binghamton	1
Ohio State	1
Arizona	1
Chicago	6
UNC Chapel Hill	1
UT Austin	1
UWM	3
UCB	24
UC Irvine	1
UCLA	1
Delaware	1
UIC	1
UIUC	1
Macau	1
Michigan	4
Ottawa	1
UPenn	2
Pittsburgh	1
Rochester	1
USC	1
Washington	1
Waterloo	1
Vanderbilt	1
Yale	2
CalTech	3
Total	192