International Mathematics Olympiad: Does Economic Performance Matter?

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Abstract

Since inception of the International Mathematics Olympiad (IMO) in Romania in 1959, over one hundred countries have participated, and a few have hosted it. China and the US have won the most gold medals and rank higher than other countries, whereas Africa and South America are yet to attain the required points to emerge as overall winners. This study employs regression-based empirical techniques to examine the determinants of success at the IMO. We find strong evidence that there is a positive effect of gender, home-country primary school enrolment rates and previous gold medal success on performance at the IMO. Economic performance however shows a weak connection with IMO performance, especially for the UK and Germany where point estimates are negative. Active national mathematics competitions and having previously hosed the IMO also reveal a positive relationship with IMO performance, particularly for the US. South Africa and Tunisia are the two African countries that have won a gold medal each, and interestingly South Africa is the only African country to have hosted the competition. Our study recommends a policy for low-income African countries to increase primary school enrolment rates, establish five mathematics competitions per state and one at the federal level, to select representatives for the IMO.

1. Introduction

Success factors are virtues that determine who gets what, at which degree, in what value and quantity. Many individuals, businesses, investors, states and even nations are learning the path of success. Many have risen to the rank of people with net worth of at least one billion, which can also be termed billionaire due to success factors. Countries like United States of America (USA), Russian Federation, United Kingdom (UK), China, Japan and so on, have become superpowers because of how they have aligned themselves with variables that determine greatness. Countries like Brazil and North Korea are emerging pacesetters because they are rapidly climbing the ladder of success. The People's Republic of China continued to dominate many market economies of the world driven by technology especially African markets. However, the same cannot be said for developing nations such as the African continent.

International Mathematics Olympiad (IMO) which dates to 1959 in Romania is one of the oldest international competitions globally. It is a mathematics competition that has spanned over sixty (60) years till date. The maiden edition was attended by seven (7) countries where Romania emerged as the outstanding team in 1959. IMO holds every year in July, with 2020 being unique as the competition was virtual in September due to outbreak of corona virus pandemic. Also, in 1980, the competition did not hold although it was to be held in Mongolia but was cancelled due to internal strife within the country, according to Wikipedia.

International Mathematics Olympiad (IMO) since its inception has been attended by over one hundred countries of the world. According to available information, European countries won the first 18^{th} edition of the competition, while United States of America (USA) became the first Non-

European country to win the competition in 1977. Hitherto, many countries across the five continents have won the competition except Africa and South America.

African countries' participation in International Mathematics Olympiad (IMO) has been quite lackadaisical, as none has gotten close to winning the competition. Africa made its debut in 1977 with Algeria making the first trip to the competition in Belgrade, Serbia. About twenty-one (21) countries participated in that year's competition with Algeria taking the back seat at 21st position that year. Only Tunisia joined its fellow North African counterpart in 1981, and they both represented Africa till 1983 when Morocco made its own debut. Hitherto, nineteen countries have since represented Africa and these include Angola, Algeria, Benin Republic, Botswana, Burkina Faso, Ivory Coast, Egypt, Ghana, Gambia, Kenya, Madagascar, Mauritania, Morocco, Nigeria, South Africa, Tunisia, Tanzania, Uganda and Zimbabwe. Only Morocco has participated more than any other African country with thirty-eight (38) appearances while Tunisia and South Africa follow closely with twenty-nine (29) appearances each.

It is imperative to investigate why countries behave the way they behave. For instance, China made its debut in 1985 and since 1988 till date; the Chinese seems to have chosen the competition as their birth right. They have won 162 gold in just 35 appearances, thereby winning the competition more than any other nation who has participated in the competition; only USA came second with 133 gold medals in 46 appearances.

Researchers, professionals, academicians, and many others have begun asking questions as to why Africa is yet to record a gold medal in IMO competition despite over 40 years of attendance, as the continent made its debut in 1977 whereas China who has bagged gold medals more than any other country, came into action eight (8) years later in 1985. Africa generally has not lived up to expectation at international scenes, though; individuals have shown exceptional qualities in

different fields. What could be responsible for the momentum that other countries like China, USA, Russia, South Korea, Bulgaria etc. are enjoying? Is the game so tactical that Africa could not form a solid team? Perhaps Africa came too late to the party in 1977 or economic factors such as investment, Gross Domestic Product (GDP), savings, human capital, investment and the likes have served as major roadblocks? This study seeks to answer these and many other interlaced questions on why African countries behave the way they do in International Mathematics Olympiad, as well as success factors behind dominant forces of China, USA, Russian Federation and so on.

2. Review of Related Literature

In this section, we review some theories and other works that are closely related to the current study. We shall also give a surmised rundown of International Mathematics Olympiad since 1959.

2.1 Brief History of International Mathematics Olympiad (IMO).

International Mathematics Olympiad (IMO) is a mathematics competition that is usually attended by high school students from different countries. (Study.com) posits that IMO contests aim to foster interest in and improve the mathematical skills of participants through team-based competitions.

The IMO is a mathematics Olympiad for pre-college students and is the oldest of the International Science Olympiads. The first IMO was held in Romania in 1959. It has since been held annually, except in 1980. More than 100 countries, representing over 90% of the world's population, send teams of up to six students, plus one team leader, one deputy leader, and observers. North Korea was disqualified for cheating at the 32nd IMO in 1991 and again at the 51st IMO in 2010. It is the only country to have been accused of cheating. According to IMO official, IMO flag was introduced at IMO 1995 in Canada along with the IMO logo. The flag is white with the IMO logo

in its center. It became a tradition that the IMO flag is passed to the next host at the end of the closing ceremony. The IMO hymn was introduced at IMO 1997 in Argentina.

2.2 Closely related theories

This study will adopt theories of Human Capital Development and Vicious Circle of Poverty. The reason for their adoption is not farfetched, as both theories have a direct relationship with productivity.

Alfred Marshal (1890) states that health and strength whether mental, and moral . . . are the basis of industrial wealth which lies on the fact that when wisely used, it increases the physical, mental, and moral health, strength, and vitality of the human race. In other words, development and growth of any nation depends on its available and deployable human resources. Human capital is the term economists often use for education, health, and other human capacities that can raise productivity when improved upon (Todaro & Smith 2003).

Given the above definitions, Human Capital Development (HCD) comprises of factors such as education, health and other forms of formal or informal trainings that can raise human productivity and development. These determinants are essential to HCD as only persons with the right mentality will aim at being prolific. This further leads us to another theory - Vicious Circle of Poverty.

Nurkseis (1961, 1952, 1953) assets that the Vicious Cycle of Poverty is the circular constellation of forces tending to act and react to one another in such a way as to keep a poor country in a state of poverty. For instance, a poor man does not get enough food which makes him weak, and consequently reduces his efficiency, leading to low income and remaining poor. It is a force that tends to keep a man in the state of poverty because he is poor.

Aggregating the above theories together, it is obvious that both the human capital development (HCD) and vicious cycle of poverty work directly to affect humans psychologically, mentally and physically as it goes a long way in determining the future of a nation. This paper intends to investigate whether these factors could be affecting Africa's performance in IMO or maybe other underlying factors exist that are thwarting the performances of African countries in IMO competitions. This study will examine the effect of various factors mitigating against African countries and variables contributing to the impressive momentum of countries like China and USA.

3. Data and Empirical Analysis

This study employs descriptive and empirical techniques of analysis in order to examine determinants of success in International Mathematics Olympiad (IMO). The data to be used are sourced from World Development Indicator (WDI), International Mathematics Olympiad (IMO) official website, UNESCO Institute of statistics, Louis Fred official, Trading Economics, and Wikipedia. This section will be divided into two segments; first is the empirical analysis of determining success factors in IMO competition among the most ranked countries in the competition, second is the descriptive analysis of all countries in Africa that have ever participated in the competition year after year. Specifically, econometrics method of data analysis will be used for data collected from different sources. It is pertinent because econometrics is the application of mathematical statistics to economic data to lend empirical support to the models constructed by mathematical economics and to obtain numerical estimate (Samuelson et al, 1954).

In an attempt to examine the factors that has contributed to the success of most ranked countries in International Mathematics Olympiad (IMO), it is necessary to develop a model to justify the

correlation that exists between the two variables. In this regard, a multiple regression model is thus developed to accomplish the objectives of this study.

The model for this study is theoretically based on Total Points (TP) which depends on Government's Expenditure on Education (GEE), Primary school Enrolment Rate (PER), Host Country (HC), Economic Growth that is Per Capita Growth and Per Capital Income (EG), Mathematics Competition (MC), Female Student (FS), Male Student (MS) and Gold Medal (GM),

Thus, the model can be theoretically stated as: $Y = f(GEE, PER, HC, EG, MC, FS, MS, GM)$

TP (Y) is chosen as a proxy for Performance of countries in IMO because it reveals the overall contribution of each team member which comprises of both male and female. Also, it is basis on which the winner of the competition is determined.

(GEE) Government's Expenditure on Education is chosen as proxy for Human capital investment because the concept entails increase in human capacity. It is a percentage of total government expenditure.

(PER) is proxy for Primary school Enrolment Rate because primary education provides children with basic reading, writing, and mathematics skills along with an elementary understanding of other subject (Word Bank).

(HC) Host country represents if hosting the competition at a particular point in time is a determinant factor in winning the competition.

(EG) Economic growth will be proxy by GDP per capita growth (annual %) and Real Per capita income at current USD. It is a true representation of economic growth because it reveals income per head which include pupils and students.

(MC) Mathematics Competition is selected to proxy previous and present national mathematics competition taken by the students before attending International Mathematics Olympiad (IMO).

(FS) Female Student and (MS) Male Student are used to proxy gender contribution to the points won by the winning countries.

(GM) Gold Medal is chosen to proxy contribution of gold won by the team member to the total points.

By transforming the above into linear form,

$$Y = \beta_o + \beta_1 GEE + \beta_2 PER + \beta_3 HC + \beta_4 EG + \beta_5 MC + \beta_6 FS + \beta_7 MS + \beta_8 GM + \mu \qquad (1)$$

where:

Y= Performance in IMO, the dependent variable

β_1-β_8 is the co-efficient estimator for each of the independent variables

μ = Stochastic error term, that is factors that cannot be explained by the independent variables.

There is need to state the apriori expectation of each independent variable. The economic apriori criteria refer to the sign and size of the parameters and the economic relationship between the variables. The apriori expression of this multiple regression model is $\beta_1 > 0$; $\beta_2 > 0$; $\beta_3 > 0$; $\beta_4 > 0$; $\beta_5 > 0$; $\beta_6 > 0$; $\beta_7 > 0$; $\beta_8 > 0$

A positive sign is expected from the coefficient of the relationship between TP (Y) GEE, PER, HC, EG, MC, FS, MS and GM.

The specification in equation (1) will be estimated using Ordinary Least Square (OLS) to determine factors that contribute to high scores in International Mathematics Olympiad (IMO). Due to insufficiency of data among the countries, Total Points (y) will be estimated using different

variables. For example, Chinese Total Points may be estimated by six out of eight available variables, while USA may be estimated with just seven variables.

4. Presentation of Results and Findings

Regression Analysis for China

Dependent variable = Total Points in IMO

R- squared 0.8546 Prob > F 0.0000
Adjusted R squared 0.8110

Independent Variables	Co-efficient	P-value
Male Student	33.8125***	0.000
Female Student	36.89953***	0.001
Gold Medal	11.34848***	0.006
Primary Enrolment Rate	1.265601***	0.002
Host Country	18.01374	0.168
Per Capita Growth	.5094675	0.704
Constant	-194.3819	0.002

Source: Stata 14. *, **, *** Significant at the 10, 5 and 1 percent levels

The above table shows conformity of all independent variables with apriori expectation; positive signs are expected from all the variables. Only four variables are statistically significant at all level. The implication of the above results is that a male student gives additional score of 33.81 to the over total point (TP), while addition of female student gives extra score of 36.9 to the total score (TP). Also, winning at least a gold medal in previous year gives extra score of 11.35, while an increase in enrolment rate in China adds about 1.27 to the entire total points (TP). In essence, participation of male and female students in IMO competition for China have added more points to their winning points in this competition. When the Chinese team win at least a gold medal in the competition, they stand a chance of racking more points about 11.35 in the following year.

The rate of enrolment into primary schools in China shows a positive effect on total points gathered in IMO, which means as more pupils are being enrolled into primary schools, the better their chances of winning the competition. Host Country (HC) explains the importance of hosting the competition, which means that a country hosting the competition at any particular point in timegives such country tactical knowledge about the competition. In the case of China, hosting the competition shows a positive relationship with the total points won but is not statistically significant at all level. It is believed that per capita income is a true representation of economic growth, though this depends largely on the income class prevailing in such country. Per capita growth rate reveals a positive relationship with the Total Points (TP) but is not statistically significant at all level. The indication is that being dominant in this competition is not tied to economic growth, GDP or being a host at one point in time.

The above independent variables can only explain about 85% of the variance in the dependent variable (TP) Total Points. That is Male Student, Female Student, Gold Medal, Primary Enrolment Rate, Host Country, and Per Capita Growth in our model can only explain 85% of the factors which is behind the momentum that the Chinese team is enjoying in the competition. Again, there are other factors of about 15% given the above R-squared that our model cannot capture.

4.1 Regression Analysis for United States of America

Dependent variable = Total Points in IMO

R- squared 0.6012	Prob > F 0.0000	
Adjusted R squared 0.5366		
Independent Variables	Co-efficient	P-value
Male Student	18.10381***	0.000
Female Student	.6255395	0.867
Gold Medal	10.82318***	0.000
Mathematics	4.741169**	0.013
Host Country	35.13626**	0.039
Per Capita Growth	-1.271053	0.503
Constant	-79.55908	0.166

Source: Stata 14. *, **, *** Significant at the 10, 5 and 1 percent levels.

Regression analysis for United States of America is shown in the table above, out of all the six (6) independent variables, only four is statistically significant at both 1% and 5% given their P-value. When a male student participates in IMO competition for USA, there is a chance of winning additional score of 18.10 out of total points (TP). In the same vein, a female student can increase the score by 0.63 but this is not statistically significant. The implication of the above is that America has achieved great height in this competition with more males than females. When USA wins at least a gold medal in previous competition, it will likely increase their total point by 10.82 in the current year. Winning at least a gold medal seems to be a boost to racking most points in this competition. International Mathematics of Olympiad (IMO) dated back to 1959 and America made its debut in 1977 Olympiad. The American Mathematics Competitions goes way back to 20th century as a mathematics competition that determines who represents the Americans in IMO. The numbers of mathematics questions in this competition vary from one year to another. Given the above regression results, a change in number of questions attempted by the students before going to the IMO competition increases their total scores (TP) by 4.74. This is statistically significant at 5% given the p-value. Mathematics competition (MC) reveals a positive relationship with total point racked up in this competition.

Being a host in this competition shows an immense relationship with the total score (TP). Hosting the competition is like learning the way of success. If USA hosts this competition, it increases their scores by 35.14 and is significant at 5%. In the case of China, this is not significant, but it shows a direct relationship. Out of the six (6) independent variables, 5 conformed to apriori expectation with positive signs while Per capita growth rate shows a negative relationship but is not statistically significant at all levels. This shows that economic growth doesn't determine American success in

International mathematics Olympiad (IMO). The model for this study can only explain about 60% of the variance in Total Points (TP). Again about 40% of the factors responsible for American good performance in Olympiad cannot be explained by the model.

4.2 Regression Analysis for United Kingdom.

Dependent variable = Total Points.

R- squared 0.7295 Prob > F 0.0000		
Adjusted R squared 0.6642		
Independent Variables	Co-efficient	P-value
Male Student	15.3873 **	0.026
Female Student	14.24532	0.204
Gold Medal	21.90717***	0.000
Expenditure on Education	9.015623	0.292
Host Country	17.80484	0.525
Primary Enrolment Rate	2.852981	0.179
Per Capita Income	-.0020586**	0.032
Constant	-266.1958	0.258

Source: Stata 14. *, **, *** Significant at the 10, 5 and 1 percent levels.

The above regression table for UK shows that only three (3) variables are statistically significant at 1% and 5% only. Also, these variables jointly predict total score (TP) won by UK's team in IMO, as the p-value associated with the F value is less than 5% significant. Positive relationship is expected from all the independent variables with the dependent variable total score (TP) but one of them reveals negativity. Per capita income determines GDP per head, which is important because it shows the spread of the income across the nuke and crannies of the country. A change in per capita income decreases total score (TP) by 0.0021, though, this rate is too low but the negative effect is a concern. The reason for a negative effect might be due to the fact that, UK's

performance in IMO has been quite unimpressive when comparing their dominance in the world economy, politics and education. The implication of the above is that UK has done better in IMO when their economy was at minimal stage.

Male students have been instrumental to UK in being ranked high in IMO competition. A male student increases total score (TP) by 15.39 and is significant at 5%, female student shows a positive impact but is not significant at all levels. Winning at least a gold medal increases chance of being dominant in this competition. It is significant at all levels. Increase in government expenditure on education tends to improve the face of education sector, even sometimes it increases enrolment rate. Percentage change in government expenditure and primary enrolment rate in UK improve total score (TP) but is not statistically significant at all levels. Hosting the competition at one point in time is not significant in winning the competition. The above R-squared indicates that about 73% of the variance in total score (TP) has been explained by the model in this study, while 27% is left unexplained.

4.3 Regression Analysis for Germany

Dependent variable = Total Points.

R- squared 0.6746Prob > F 0.0000		
Adjusted R squared 0.6281		
Independent Variables	Co-efficient	P-value
Male Student	18.1504 ***	0.007
Female Student	26.16306**	0.023
Gold Medal	16.35355***	0.000
Host Country	4.483325	0.817
Per Capita Income	-.002743***	0.004
Constant	104.1754	0.065

Source: Stata 14. *, **, *** Significant at the 10, 5 and 1 percent levels.

From the above table, regression analysis reveals conformity with apriori expectation except per capita income. Male student participation increases score by 18.15, while female student increases score by 26.16. Gold medal in previous competition increases score by 16.35 in the current

competition. Hosting the competition does nothing to influence their chances in racking more points because the parameter is not statistically significant at all level. For the second time, per capita income shows a negative relationship with total points (TP) in the competition. This is statistically significant at all levels. This posits that, as the economy grows better, there is likelihood of total score being decreased by 0.0027. Base of F-statistics P-value, Male student, Female student, Gold medal and per capital income jointly predict total score of Germany in IMO because it is less than 5% significant level. The model above can only explain 68% of the variance in total point (TP) given the R-squared, while remaining 32% cannot be explained.

4.4 Descriptive Analysis

Table 1.1a

7 MOST APPEARED COUNTRIES ON IMO

Rank	COUNTRIES	TIMES ON IMO
1	Romania	61
2	Bulgaria	61
3	Hungary	60
4	Poland	60
5	UK	53
6	Sweden	53
7	France	51

Source: IMO website

Table 1.1b

7 COUNTRIES WITH MOST GOLD

Rank	COUNTRIES	NO OF GOLD	TIMES ON IMO
1	China	162	35
2	USA	133	46
3	Russia	101	29
4	Hungary	85	60
5	S/Korea	81	33
6	Romania	78	61
7	Soviet Union	77	29

Source: IMO website

Table 1.1a depicts seven countries that have appeared most in IMO since its inception in 1959. Romania and Bulgaria have most appearances (61); Hungary and Poland appeared 60 times; United Kingdom and Sweden have appeared 53 times; and France with 51 appearances.

Table 1.1b shows countries with the most wins in this competition: China and USA have won more gold than any other country with just 35 and 46 appearances respectively. Again, Russian has achieved a lot with just 29 appearances in the competition. Lastly, Romania has most of the appearances with just 78 gold medals. The implication of the above is that countries that have hosted more of the competition have performed below expectation when compared with China and United States that have hosted it twice or thrice. Also, countries with most appearances have achieved below every expectation. The reason while China and United Sates of America have won more gold medal than their total appearances in the competition is not far-fetched, as in this competition, from 1969-1981, there was at most 8 representatives for each country, in 1982, we have at most 4 representatives for each country and in 1982-2020, there are has been at most 6 representatives for each country. The salient factor is that a country can win as much gold medal as the number of her representative.

4.5 Descriptive Analysis of Africa's Performance at the International Mathematics Olympiad IMO

No of Participation (1 – 4) times	Countries	Gold	Silver	Bronze
1	Angola	0	0	0
1	Burkina Faso	0	0	0
1	Gambia	0	0	0
1	Madagascar	0	0	0
2	Benin	0	0	0
2	Zimbabwe	0	0	0
3	Mozambique	0	0	0
4	Egypt	0	0	0
4	Kenya	0	0	0

Source: IMO official site

From the above table, Angola, Burkina Faso, Gambia and Madagascar has participated in IMO for once, while Benin Republic and Zimbabwe have participated twice, whereas Egypt and Kenya

have participated in the competition four times. None of the above country has won Gold, Silver or Bronze.

No of Participation (5-9) times	Countries	Gold	Silver	Bronze
6	Botswana	0	0	0
6	Ivory Coast	0	1	0
7	Tanzania	0	0	0
7	Ghana	0	0	1
9	Uganda	0	0	0

Source: IMO Official site

From the above table, Botswana & Ivory Coast have participated six times, Tanzania, Ghana & Uganda have participated seven times each while Uganda have participated 9 times.

No of Participation (10-40) times	Countries	Gold	Silver	Bronze
13	Nigeria	0	0	5
19	Algeria	0	2	5
29	Tunisia	1	5	16
29	South Africa	1	9	49
38	Morocco	0	4	35

Source: IMO Official website

From the above descriptive tables, only 19 countries from Africa have participated in the competition with two gold medals won. South Africa and Tunisia are the only African countries to win gold medal; they both won one each. Morocco is the only country with most appearances (38), and the country is yet to record a gold medal, while nine (9) countries have less than 5 appearances. Generally, African countries have low participation in this competition, the continent lacks consistency. Countries like Algeria which is the first African country to be in 1977, have only 19 appearances to her name while Tunisia, South Africa and Morocco who came in 1981 and 1983 respectively have appeared more than Algeria. Also, countries like Burkina Faso, Benin Republic, and Zimbabwe had their last appearances in 2014. Nigeria made its debut in 2006 and

has missed two of the competition since 2006, while Ivory Coast who made its debut in 2010 have also missed 5 competitions since 2010. These figures show that many African countries have not really shown seriousness in this competition through their lack of consistency. South Africa is the only African country to have hosted the competition in 2014.

5. Conclusion

Human capital is the most asset that any country can ever poses, as there cannot be precious utilization of mineral resources without proper investment on human capital. The above analysis reveals that gender has played decisive role in total points racked up in the competition. Male students have added more points to the total score than female counterpart, though on two occasions, Female student have increased score more than their male counterpart in China and Germany. However, majority of the countries have attended this competition with more male students than female students. Since 1986, the Chinese team has never had a female student. In order to encourage more female students to participate in the mathematical competition, starting from 2002, China Mathematical Olympiad Committee conducted the China Girls' mathematical Olympiad. Again, the top two winners will be admitted directly into the national training team (Xiong Bin & Lee Peng Yee, 2007). It is from the national training team that the best students are selected to represent China in IMO. Chinese government has encouraged more female participation in International Mathematics Olympiad, and this might be one of the reasons they have achieved more in this competition.

Wining at least a gold medal in previous competition can increase team's chances of racking more points in the current competition, this shows a huge effect on all the countries analyzed. Hosting International Mathematics Olympiad is believed to be a decisive factor in winning the subsequent edition in other countries, but this has not been proven beyond a reasonable doubt. China, UK, and Germany have hosted this competition at most four times. For instance, China have hosted the competition four times, Germany - four times, United Kingdom - three times, and USA - two times. From all these countries, only USA has been significantly impacted with hosting the competition, while others are not. It might be statistically safe to say that hosting the competition has little effect in winning the competition.

Rationale behind success in this competition is vast but only few can be quantitatively analyzed. Previous mathematics questions taken by the students before going to the competition is vital as it has ensured USA wins more points in this competition by using the American Mathematics Competitions at different stages to ensure who will qualify for this competition. In china, there is China Mathematical Competition which ensures the best students are being admitted to China Mathematical Olympiad, then few are selected to form a national training team where representatives for International Mathematics Olympiad are chosen. This shows the seriousness that government has shown for this competition.

Government expenditure on education has little effect on performances in IMO because the positive relationship lacks statistical significance across all the countries. Primary enrolment rate in China shows a positive effect on total points in this competition while that of UK is not statistically significant. Chances of getting talented students may increase as more pupils are being admitted into primary schools.

Finally, economic growth has significantly decreased performance in this competition as the evidence can be seen from results of UK and Germany. Chinese economy shows positivity but is not significant, United States reveals negativity but is insignificant as well, while that of UK and Germany show huge negativity with significance. Thus, economic performance of countries may be secondary as the impact can sometimes be underwhelming.

6. Policy Recommendations

Below are policy recommendations to boost African performance in International Mathematics Olympiad:

I. First and foremost, there should be an intense awareness of this competition (IMO) in every school, and it should be included in the curriculum of every African school according to the nation's university standards.

II. There should be a policy change in the educational sector aimed at establishing not less than five mathematics competition in each state of the federation, and federal mathematics competition must also be established to absorb top students from state level competition. Mathematics competition at state level should be graded from level 1-5, only best students should be allowed to progress to the next level, until level 5 is reached. Level one (1) should be from the grassroots that is local government, while level five will be for state level.

III. Education funding should be immensely increased, so that dilapidated structure can be renovated, as well as building new structures in order to reduce teacher to student ratio. Teacher’s salaries should be reviewed to ensure students and pupils are getting the best from their teachers. To increase efficiency of the teachers, take home of every teacher

should be improved to meet world standards. African countries need to do more by adequately preparing, investing more in education, and having a long-term plan to bag medals especially gold in the competition.

IV. Government of every African country should ensure that their teams participate in every concurrent International Mathematics Olympiad (IMO). This will ensure consistency and may improve performances in the long run from experiences gained and mistakes to be learnt from.

V. According to Ellison and Swanson (2018), in the US, girls are underrepresented in high mathematical attainment, and there is a widening of the math gap over the high school years - even among the top achievers. Agarwal and Gaule (2020) find that IMO participants from low-income countries produce 34 percent fewer publications and 56 percent fewer citations than equally talented rich-country counterparts. Our paper proposes that this underperformance of low-income countries can in part be explained by weak primary school enrollment rates across these countries, especially in the bottom low-income countries and among females. Thus, a dual policy to increase primary enrolment rates and further incentive the enrolment of females at schools where they can get high quality early education, will contribute to limiting the observed gap in attainment in low-income countries and across genders

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