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Quantile Analysis of the Mathematics Achievement - Attitude Relationship by Gender

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Abstract

In this paper, we report some findings of a study on attitude and mathematics achievement at the senior secondary school level in Botswana. We adopted a new methodology in the analysis of the relationship between attitude, gender bias and achievement in mathematics with gender as a dummy variable. The method, quantile regression (QReg), was used because it unveils the relationship at the quantile (percentile) levels and does not require the parametric assumptions used in the Ordinary Least Square Regression (OLS). The findings showed that positive attitude significantly influenced the mathematics achievement of students in the OLS model but was not significant at the 95^{th} percentile in the QReg. These findings implied that at the uppermost tail of mathematics achievements, there were some other variables that better explained mathematics achievements. Furthermore, using this method, gender bias and female factors did not influence achievements significantly. Finally, we hope that this study would open up a new research frontier by encouraging researchers to study the mathematics achievement-attitude relationship at the quantiles rather than generalizing the relationship across all levels of students' ability.

Keywords: Mathematics attitudes, achievement, gender, quantile regression.

Background of the Study

The relationship between attitudes and mathematics performance has been of interest to researchers for many years (Aiken, 1970; Chionh & Fraser, 2009; Yara, 2009a,b; Forgasz & Rivera, 2012). Mathematics subject is failed by many learners around the world and mathematics educators have been of the view that poor attitudes towards the subject could be contributing to low achievement. A number of studies have indicated significant relationships between mathematics achievement and attitudes (Aiken, 1970; Masquad, 1992; Ma, 1997; Sherman & Christian 1999; Sriraman, 2007; Yara, 2009a,b; Forgasz 2012). The findings of these studies have raised interest for further research and deeper understanding of the relationship between achievement, attitudes and other related parameters. However, the use of classical statistical techniques in the analysis of the achievement-attitude relationship, like the Ordinary Least Square (OLS) regression have, focused mainly on the conditional mean distributions of the relationship and do not examine the relationship at various achievement levels (Depaolo & Mclaren 2006; Forgasz & Rivera 2012).

A number of attitudinal variables such as motivation, confidence, values, enjoyment, gender beliefs and others have been associated with achievement in mathematics. Studies on these variables have also indicated gender differences in mathematical performance at different levels of schooling where girls' self-esteem, confidence in their mathematical abilities, expectations for life, interest in challenging courses and rewarding careers, and pursuits in mathematics declined as they got older and had lower performance in the subject (AAUW, 1994; Swetman, 1995; Beilock, et al 2010). Some efforts geared to improve girls' attitudes towards mathematics and performance by separating boys and girls in mathematics classes in the subject (Gill, 1994; Kaino, 1998), indicated more studies were still needed to further investigate the impact of attitudes on mathematical competencies taking gender into consideration. It is also worth noting that the disparity in performance between male and female students in mathematics has been attributed to the insecurity of female mathematics teachers as noted by Beilock et al (2009). Studies in the achievement-attitude relationship remains a matter of interest till today (Yara, 2009a,b; Beilock et al 2010; Atnafu, 2011; Ahmed & Bora, 2011; Patra & Mech, 2011; Forgasz & Rivera, 2012).

Depaolo and Mclaren (2006) documented reports that emphasized that low levels of aptitude, lack of interest in mathematics and unfavorable attitudes toward the course resulted in high levels of anxiety, which lead to poor performance but these findings were generalized to all performance quantiles. In addition to the attitudinal factors, Depaolo and Mclaren (2006) further categorized ingredients of learning to include; cognitive effect, cognitive resources and environment. Although attitudes could be classified under various categories, this article concentrated on positive attitudes and gender bias (beliefs). Five attitudinal variables; *motivation, confidence*, *values, enjoyment* (positive attitude) and *gender bias* were considered in this study as these variables were of particular interest to researchers because most attitudinal variables considered in previous studies would fit into these broad categories.

Motivation has been defined as an internal process, initiated by some needs, which lead to activity, which would satisfy those needs (Lovell, 1973). Human needs, as identified by Maslow (1954), were; physiological needs, safety needs, love and belonging needs, esteem needs and the need for self-actualization. These needs are arranged in an order called hierarchy of needs. The hierarchy of needs implies that the lower order needs must be satisfied before the higher ones. It has been argued that the strength of a student’s motivation could be measured by the quantity of time the student was willing and able to spend on the given task (Carroll, 1965; Atkinson, 1980) and the amount of time spent on an academic pursuit was regarded as a predictor of students’ achievement (Berliner, 1990). Motivation could be a result of achievement goal-orientation, self-efficacy, personal interest in the task and task value beliefs (Pintrich, 1993). Motivation in mathematics could be viewed as the interest and desire to pursue studies in mathematics. Motivation could be intrinsic or extrinsic. Intrinsic motivation comes from within the individual and it is a personal motivation which comes through personal interest or desire. A student who is intrinsically motivated could undertake a learning activity for its own sake most likely because of the feelings of accomplishment it evokes. Extrinsic motivation is the kind of motivation that is exhibited as a result of expected external rewards which could be in the form of grades and other forms of incentives. An extrinsically motivated student could perform better in order to obtain some reward, get teacher’s approval and probably to avoid punishment (Gage & Berliner, 1992 ; Lepper, 1988).

Mathematics confidence has been defined as a state of being fearless in attempting mathematical tasks and has been considered to be one of the most important affective variables (Reyes, 1984). In some research on attitudes, confidence has often been measured as the opposite of anxiety (Wigfield & Meece, 1988; Richardson & Suinn, 1972). Anxiety has been associated with incompetence in mathematics achievement (Muthelo, 2003). However, some educators believe that anxiety could sometimes increase students’ adrenalin and keep them interested and alert (Gibson, 1980). Enjoyment in learning has been described as the extent to which students derive fun or satisfaction in mathematics classes or activities (Ma, 1997). Studies have shown that there is the tendency for students to enjoy the subjects which they valued (Kulm, 1980). Value of mathematics has been closely associated with enjoyment of mathematics. Students' perceptions about the value of mathematics have also been attached to performance in the subject where a high mark in mathematics was correlated with high value attributed to the subject (Fennema & Sherman, 1978; Wigfield & Meece, 1998).

The impact of gender on students' mathematics attitude remains an area of research interest (Forgasz & Rivera, 2012; Atnafu, 2011; Ahmed & Bora, 2011). These studies, reported that gender differences in mathematics still existed and that male students were more positive towards mathematics learning. However, another recent contradicting study by Vale (2012) reports that the gender gap in mathematics achievement was closing up. This contradiction stimulates the need for further studies on gender disparities in mathematics teaching and learning.

Despite many studies conducted on gender disparities, most of them did not disaggregate the impact of attitude on achievement at different quantiles. Previous models assumed that the relationship was uniform across the performance continuum because they were determined based on the Gaussian normal distribution which is based on the conditional mean (Koenker, 2005).

In the edited work of Forgasz and Rivera (2012) scholars have emphasized that modeling the achievement-attitude relationship requires analysis across the distributions. The use of relatively new methodology called Quantile Regression (QReg) helps to achieve this goal because it captures the extreme tail interaction between mathematics achievement and attitudes unlike the classical OLS regression in common use by researchers. Penner and CadwalladerOlsker (2012, p. 455) on whose work the distributional debate was centred in Forgasz and Rivera (2012) found that in Hungary, female students performed significantly better at the 10th and 25th percentiles. At the median, insignificant differences were observed between the genders while the boys performed significantly better at the 75th and 90th percentiles. However, the results for other countries examined in the analysis did not all follow the same trend as Hungary. In the unique case of Hungary, the OLS estimate showed no significant differences because the gender effect above the median cancels out the effect below it. In other countries, the differences were loaded to either of the two extremes or at the centre. The researchers concluded that since the magnitude and pattern in the distribution of performance varied diversely across the quantiles in different countries, gender differences in mathematics achievement must be largely due to social factors than otherwise. In a similar study, Tian (2006, p. 476) affirmed that previous studies focused on the conditional mean and concluded that there were differences in the way family background has effect at different quantiles of mathematical achievement in contrast to conclusions based on the OLS.

Besides the fact that QReg could capture the extreme tail behaviors of the achievement-attitude relationship, and thereby provides a more complete picture, it does not require the necessary condition of normality needed for parametric analysis (Koenker, 1978; Koenker & Hallock, 2001; Koenker, 2005). This method has been extensively used in finance and other areas of knowledge in studying the tail behaviors of variables because it is a distribution-free statistical technique but is yet to be extensively adopted in educational researches (Yue & Rue 2011; Xiao, 2009; Tian 2006). A special case of the QReg is the Median Regression that focuses on the median rather than the conditional mean in OLS. While most studies continue to study attitudes and achievement around the conditional mean (Depaolo & Mclaren, 2006; Ercikan, McCreith & Lapointe, 2005; Tian 2006; Penner & CadwalladerOlsker, 2012), it is important to find out the relative magnitude of the contribution of attitudinal variables on mathematical performance, in the presence of gender, at some quantiles of interest. In this paper, we compared the results in the relationship between mathematics achievement and attitudinal variables using OLS and QReg. The researchers were more interested in illustrating the advantage of using QReg over OLS than in establishing the relationship that we already knew existed.

Hypotheses

Although, the achievement-attitude relationship by gender remains an issue of interest and is well captured in this study, our hypothesis focuses on comparing the estimation of the relationship by OLS and QReg and we attempted to simplify our analysis well enough for all stakeholders:

H_1: The OLS regression mis-estimates the relationship between mathematics attitudes and achievement at some achievement levels.

Methodology

The study adopted the quantitative design and the researchers collected data using a mathematics test and a questionnaire. The target population was senior secondary school students in public and private schools in Botswana. The sample involved only Form 5 students selected from 5 private and 4 public senior secondary schools in Gaborone city – the capital of Botswana. The random sampling technique was used to select 2 schools from each of the school categories. After the random selection of the schools, convenience sampling was used to select the students from the schools as it permits the use of available respondents (Gay & Airasian, 2003). Twenty (20) boys and 20 girls from each school were targeted and at the end of the process, the responses from a total of 156 respondents were analysed. The constructed achievement test intended to measure students' cognitive knowledge of mathematics. The test items were taken across Bloom's (1956) taxonomy of educational objectives and the five modules in the Senior Secondary Mathematics Instructional Materials and Development Guidelines of Botswana. The questionnaire was used to gather information relating to the five attitudes of interest. The test was written after the questionnaire had been administered to ensure that the students did not carry any bias from the test into their responses to the questionnaire items. A five-point Likert – scale was used and it ranged from '1' representing *Strongly Disagree* to '5' representing S*trongly Agree*. The averages of the extent of the agreement or disagreement of the students on those questions were taken to be the extent to which students demonstrated those attitudes. The items representing positive attitude were derived from clustering 19 variables representing motivation, confidence, enjoyment and values.

Validity and Reliability

The validity types used in this study were the content validity for the achievement test items and the construct validity for the questionnaire items. Content validity that determined the degree to which the constructed test measured appropriate content area (Gay & Airasian, 2003; Nitko, 2004) was considered appropriate and was done by expert judgment. The achievement test used in the study was validated by an expert in mathematics education. Furthermore, to obtain the intended 20 questions on the achievement test, 30 questions were initially administered at the pilot school other than the four schools in the sample and the scores were used for the calculation of "*Item difficulty index (P value)*". The item difficulty index measures the extent to which the items were considered difficult. It was used to eliminate 10 questions as was found appropriate such that the 20 required questions for the study were retained. Item difficulty index is defined as:

$$P = \frac{No.C_a}{N},$$

Where P = The item difficulty index, $No.C_a$ = number of students choosing the right alternative, and N= the total number of students taking the test.

Items with very high values of difficulty index were eliminated. For example an item giving a P value of 1.00 meant that all students got it right, or with very low P value approaching zero implied that very few students got the item right. In this study, the highest values and the lowest values of P were considered to constitute poor questions. In such cases, either the item was very easy or very difficult. The researcher distributed the 30 questions constructed using a content-by-process matrix table. There were 5 attitudes with five questions for each attitude at the pilot stage. Construct validity that sought to know whether items measured the right construct underlying a variable, was used to validate the questionnaire items. In the validation process, one of the five questions measuring, *Value* was removed. The reliability of the final questionnaire was estimated using the Cronbach alpha (α) coefficients giving the following values; Motivation (.467), Confidence (.651), Values (.607) and Enjoyment (.837). The Kuder-Richardson 21 (K-R 21) test was used to measure the reliability of the mathematics achievement test questions and it returned a result of 0.52.

Data Analysis

The mean achievement was 8.7821 marks out of 20 with a standard deviation of 3.1280. The lowest score was 1 mark out of twenty while the highest was 20. The maximum obtainable rating on the positive attitude was 96 (5*19 items). The mean rating was 68.6985 with a standard deviation of 11.9965, a minimum of 42 marks and a maximum of 91 marks. There were five items for gender bias and consequently an obtainable rating of twenty five. A minimum of 5 points were scored and the maximum obtained was 22 out of the 25 marks.

Table 1: Descriptive statistics of variables

Variables	N	Mean	Standard deviation	Minimum	Maximum
Achievement	156	8.7821	3.1280	1	20
Positive attitudes	136	68.6985	11.9965	42	91
Gender bias	149	9.8456	3.8462	5	22

The OLS shows that positive attitudes have a significant impact on performance ($P<0.05$). In particular, the R squared shows that 15.38% of the variation in performance is explained by attitude while the Adjusted-R-Square indicates a 13.41% variation. The Adjusted value of R square is more acceptable in that it allows comparison between models with different number of covariates (Field, 2012). However, the two results are presented in Table 2. One could say that a unit increase in positive attitudes lead to 0.0993 unit increase in achievement (β Coefficient = 0.0993). Given the direction of gender bias, we are not disappointed that the coefficient is negative but its impact on performance is not significant ($P>0.05$). The dummy (0 for male and 1 for female) for gender reveals that female students scored about 0.5085(-0.5085) marks less than male but this difference was not found to be significant ($P>0.05$).

Table 2: Ordinary Least Square (OLS) Regression Result

	Variables	β Coefficient	t	P	R square (Adjusted-R-square)
OLS	Constant	3.3057	1.95	0.053	0.1538(0.1341)
	Gender_0_1	-.5085	-0.91	0.366	
	Positive attitudes	0.0993	4.65	0.000*	
	Gender bias	-0.1000	-1.39	0.168	

*Significant at 95% confidence level

The result from the quantile regression, implemented in Stata using the simultaneous quantile regression command, shows that attitude significantly explains the variation in students' attitudes across all the quantiles except at the 95th percentile. Gender bias was found to be statistically insignificant in the model. Similarly, being female did not have any significant effect in the model. This result is consistent with that of the OLS. However, the Pseudo-R-squares reveal that the extent of the relationship differs across the quantiles. The impact of positive attitude diminishes as progression is made towards the upper quantiles on the achievement scale (From 14.71% at the 5th quantile to 7.09% at the 95th quantile). Although, the pseudo-R-squares did not consistently decrease across the continuum, the general trend is that the OLS overestimated the relationship from the 25th quantile upwards. The impact of being female is the same in the QReg as in OLS except at the 75th percentile where girls were 0.2363 marks above their male counterparts.

Table 3: Quantile Regression (QReg) Results

Quantiles	Variables	β Coefficient	t	P	Pseudo-R-squares
Q5	Constant	-0.7000	-0.44	0.663	0.1472
	Gender_0_1	-0.1000	-0.11	-0.916	
	Positive attitudes	0.1000	4.47	0.000*	
	Gender bias	-0.1000	-1.23	0.221	
Q10	Constant	-0.1977	-0.11	0.912	0.1227
	Gender_0_1	-0.2209	-0.46	0.645	
	Positive attitudes	0.0930	3.67	0.000*	
	Gender bias	-0.0581	-1.25	0.214	
Q25	Constant	1.8757	0.81	0.419	0.0646
	Gender_0_1	-0.1243	-0.17	0.868	
	Positive attitudes	0.0791	2.94	0.004*	
	Gender bias	-0.0678	-0.77	0.440	
Q50	Constant	3.0728	1.34	0.183	0.0912
	Gender_0_1	-0.4223	-0.66	0.512	
	Positive attitudes	0.0874	3.49	0.001*	
	Gender bias	-0.0534	-0.61	0.543	
Q75	Constant	3.8386	2.22	0.028*	0.1053
	Gender_0_1	0.2363	0.25	0.807	
	Positive attitudes	0.1095	6.13	0.000*	
	Gender bias	-0.0836	-0.64	0.524	
Q90	Constant	8.4000	2.30	0.023*	0.0659
	Gender_0_1	-0.8	-0.67	0.504	
	Positive attitudes	0.12	2.90	0.004*	
	Gender bias	-0.36	-1.82	0.070	
Q95	Constant	9.25	1.42	0.157	0.0884
	Gender_0_1	-1.3160	-0.93	0.353	
	Positive attitudes	0.1085	1.49	0.138	
	Gender bias	-0.2311	-0.81	0.420	

*Significant at 95% confidence level

Discussion of Findings

The findings showed that mathematics achievement was significantly related to the attitudes of students towards the subject as the direction of positive attitudes in the models remained positive as hypothesized. The findings obtained using the Quantile Regression (QReg) established that the relationship was significant across all the quantiles except at the 95th percentile meaning that achievement-attitude relationship did not yield significant results among the topmost 5% of the sample considered. The gender bias yielded negative results in the Ordinary Least Square (OLS) and across all achievement levels in the QReg indicating that gender bias impacted negatively on students' performance, though not to a statistically significant extent. Furthermore, there were differences in the mathematics achievement between the two genders as indicated by the dummy variable but also not statistically significant. The analysis of the effect of being female showed that female students consistently performed lower than their male counterparts except at the 75th percentile in the QReg. This finding contradicts Vale's (2012) view that the gender gap was closing in mathematics achievement.

The OLS regression explained only 13.41% of the variation in achievement. Generally, the trend in the analysis shows that the achievement-attitude relationship was strongest at the 5th and 10th percentile with pseudo - R - squares of 14.72% and 12.27% respectively indicating that more factors were required to explain the gender disparities in the achievement-attitude relationship. However, the use of QReg facilitated the understanding of the achievement-attitude relationship at the quantiles (Penner & CadwalladerOlsker, 2012; Tian, 2006). This finding implies that most previous studies effectively captured the direction of the relationship between achievement and positive attitude, gender bias and the effect of gender on the achievement attitude relationship but did not effectively capture the magnitude and distribution of the relationship at different achievement levels.

Therefore, apart from establishing the relationship between achievement and positive attitudes, gender bias and the effect of gender in the relationship, the study found that there were differences across the quantiles as expected (Koenker, 2005; Penner & CadwalladerOlsker, 2012). The measure of this relationship at the quantiles above the 10th percentile was reasonably different from the OLS estimate. This finding indicated that the OLS mis-estimates the relationship at some quantiles. For example, in this study, the relationship modeled by the OLS was more typical of the students in the lower 10% of the sample while it was an overestimate for students in the upper quantiles. The result follows a trend where the relationship is loaded at the lower tail (Penner & CadwalladerOlsker, 2012).

It was plausible that the findings of this study further established that positive attitudes towards mathematics was a major determinant of students' achievement in the subject. Similar findings were established in previous studies by Fennema and Sherman (1978), Wigfield and Meece (1998), Aiken (1970), Masquad (1992), Ma (1997), Sherman and Christian (1999), Sriraman (2007), Yara (2009a,b) and Forgasz and Rivera (2012). However, we noted that most of these studies did not consider the distributional effect of educational variables across performance niches as considered in this study.

Conclusion

The method used in this study showed that there was a statistically significant relationship between attitudes and achievements in mathematics and the relationship was stronger at the lower quantiles. We also established that gender bias was not significantly impacting the performance of students. The amount of variation in performance explained by attitude revealed that there were other variables that impacted on students' performance particularly at the upper quantiles among high achievers. It rather seemed that previous models used to determine the relationship between attitudes and achievements either over estimated or under estimated the achievement-attitude relationship at different achievement levels that this method was able to underscore. The overestimation or underestimation of the achievement-attitude relationship could be the result of smoothening the relationship across the continuum thereby resulting in a fixed slope. The authors believe that the adoption of QReg would provide an alternative analytical tool to educational researchers whose data may violate the parametric assumptions and facilitate understanding of the mathematics achievement-attitude relationship at different achievement levels.

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