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RESEARCH ARTICLE

Variable selection via the adaptive elastic net: mathematics success of the students in Singapore and Turkey

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Abstract

The quality of education is crucial for its competitiveness in the developing world. International tests are organized at regular intervals to measure the quality of education and to see the place in the ranking of countries. The surveys on these examinations have provided a large number of variables that can be effective on the test scores, including family, teacher, school and course equipment and information communication technologies, etc. The important question is which variables are relevant for student achievement in these tests. The barriers of mathematics success of Turkish students in the TIMSS (International Mathematics and Science Study) exam were investigated and compared their status with Singaporean students who took part in at the top of the ranking in the exam. To do this, the adaptive elastic net which is one of the regularized regression methods was applied and compared their prediction accuracy according to three different alpha levels [0.1; 0.5; 0.9]. The findings indicate that individual, institutional, socioeconomic factors such as talented teachers, less homework, less extensive textbooks, and lessons that improving cognitive ability; home education resources as well as technological factors are effective in the educational performances of countries. The findings suggest that, a technology-oriented education system and these individual, institutional, socioeconomic factors can help increase the success of students in Turkey along with other countries which are having similar experiences in international tests.

Keywords: *Adaptive Elastic Net, Education, Machine Learning, Oracle Properties, TIMSSs*

JEL Codes: *A20, I21, C55*

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1. INTRODUCTION

Education is a key factor in the development of individuals and communities. For this important reason, various tests are conducted to see the educational status of countries and their rankings among other countries. These tests are important resources for individuals and institutions in determining the factors affecting the educational performance of countries and formulating educational policies. The 3rd must be removed. Trends in International Mathematics and Science Study (TIMSS) is one of the several international tests which measures educational performance. Understanding this test is very important in order to improve education from various aspects.

The huge educational data and information about students' and families' backgrounds and school characteristics can be obtained from the TIMSS test for researchers. It is applied to the 4th grade students aged 9.5 and older and the 8th grade students aged 13.5 and older, according to the International Standard Classification of Education (ISCED) developed by United Nations Educational, Scientific and Cultural Organization (UNESCO) (Martin et al. 2016). This is a test where students are asked various questions about their social and school lives, basic demographic information, home and environmental questions, school atmosphere, self-understanding, mathematics, and scientific studies as well as mathematics and science curriculum questions. Many different educational inputs affect educational performances of the countries directly or indirectly. The variable selection is a very important issue for determining variables, which are important for prediction of educational performances.

In the machine learning literature, least absolute shrinkage and selection operator (LASSO) and elastic net regression are the most commonly utilized variable selection and regularization methods that detect the subset of the "true" variable set of model and the optimal estimation rate. However, such method does not have any oracle properties: a) the asymptotic normality and b) the consistency in the variable selection. Zou (2006) proved that once a variable is selected from a set of considered variables, all variables are automatically selected from this set while constructing the model because of oracle properties of the adaptive LASSO procedure. However, because of the drawback of the adaptive LASSO in the case of collinearity, the adaptive elastic net method was proposed by Zou and Zhang (2009). The adaptive elastic net method can be employed to overcome the collinearity problem that might occur in variables by eliminating the parameter inconsistency and the variable selection bias as result of its oracle properties.

The aim of the study is to determine the effective variables on the student achievement of TIMSS in Turkey and Singapore to reveal the similarities and differences of the factors of educational performances between these two countries. The LASSO regression is a good variable selection method. The Elastic net regression takes into account multicollinearity (it means that there are high linear correlations between two or more explanatory variables) while performing variable selection. The adaptive elastic net regression has both these properties of lasso and elastic net regressions as well as oracle properties. For these reasons, the LASSO elastic net and the adaptive elastic net regression methods are applied on large-scale TIMSS data and are employed to compare forecasting accuracies of these models.

Table 1. The 8th Grade TIMSS Mathematics Performance by Years: Turkey and Singapore

Year	Number of participant Countries	Mathematics Score of TR	Rank(TR)	Mathematics Score of SGP	Rank(SGP)
1995	41	-	-	643	1
1999	38	429	31	604	1
2003	46	-	-	605	1
2007	50	432	30	593	3
2011	45	452	24	611	2
2015	50	458	24	621	1

Table 1 shows the 8th grade TIMSS mathematics performance by years for Turkey (TR) and Singapore (SGP). Turkey participated in 1999 for the first time in the TIMSS test and took 429 points. The rank of success of Turkey in mathematics score was 31 out of 38 countries. While Singapore has the highest achieving students in international education rankings with its teenagers coming at the top in mathematics tests, Turkey is still not good enough.

There are a few studies in the literature analyzing the TIMSS exam results through machine learning methods. For example, Filiz and Öz (2020) applied educational data mining on TIMSS 2015 the 8th grade Turkish students' data. They aimed to find best performer algorithm to classifying students' mathematic success and extract important features on success. The best algorithms were found as logistic regression and support vector machines. The "home educational resources", "student confident in mathematics" and "mathematics achievement too low for estimation" were selected as the most effective features on success. Filiz and Öz (2019) were purposed to find the algorithms that are the most appropriate for classifying the successes of students, especially in science subjects, and to determine the significant factors on this success by using the results of TIMSS 2015 8th grade Turkish students' data. Logistic regression and support vector machines were found as the most appropriate methods. The "computer tablet shared", "extra lessons last 12 month", "extra lessons how many month", "how far in education do you expect to go", "home educational resources", and "student confident in science" were selected as the most significant features in science success. Yoo (2018) utilized an elastic net method with a logistic regression model to determine the effective factors on TIMSS 2011 Korean 4th grade students' mathematics achievement. Among 162 TIMSS variables, 12 students and 5 teacher variables were selected through the elastic net method. Depren et al. (2017) employed a decision tree, a bayesian network, a logistic regression and neural network methods to determinate the TIMSS 2011 mathematics achievement factors for the 8th grade Turkish students. They found that the logistic regression was the best algorithm for the selection of the factors. Yoo and Rho (2017) applied random forest which was a supervised machine learning algorithm to determine the significant factors for the TIMSS 2015 Korean 8th graders' student, teacher, and school datasets such as "students' extra lessons or tutoring the last 12 months", "gen\years been teaching" and "total instructional hours per year". The highest relevant variables of TIMSS were found in the variables obtained from students' datasets.

In Yoo and Rho (2017) study, a data set with a total of 413 variables, consisting of 147 students, 175 teachers and 91 school variables, was used to investigate the important variables that affect the mathematics achievement of Korean students. 17 student variables were found possessing more than 20 variable significance. These variables measured students' math self-efficacy, confidence, and interest, math extra lessons, science self-efficacy, self-confidence, time spent on science homework and desire for education, the amount of books in the house and the education level of the father.

This study differs from other studies in the literature in terms of using adaptive elastic net regression, which is an advanced method enjoys oracle properties, in investigating the factors that determine the success of TIMMS. In addition, Singapore, which is a very successful country in TIMSS exams, and Turkey, which has average score, have been compared and their similarities and differences have been revealed.

2. METHODOLOGY

2.1. Adaptive Elastic Net

The least squares (LS) is an estimation method that gives all nonzero coefficients under fundamental assumptions such as linearity, homoscedasticity, independence and normality. In the literature, the subset of significant effective variables on the response variable utilizes the best-subset selection and stepwise selection procedures. Unfortunately, in datasets with a large number of explanatory variables, the best-subset selection procedure is infeasible since there is a need for many models to be estimated (Breiman 1995). In stepwise selection, the number of potential models to be estimated is less than in the best subset selection. However, this does not indicate that it is a more suitable model selection method, as stochastic errors are ignored in the variable selection step (Fan and Li 2004). Moreover, this can result in a locally optimal solution instead of global optimal solution especially if explanatory variables are associated (Shen and Ye 2002). Hoerl and Kennard (1970) proposed the ridge regression which is a superior method compared to the LS in terms of variance reduction when the multicollinearity problem arises among variables of large datasets. However, the ridge regression coefficients are not equal to zero since the method is not a variable selection procedure.

The LASSO method developed by Tibshirani (1996) provides a consistent selection of a subset of the relevant variables and predicted of model coefficients in a model. The LASSO estimator is as follows;

$$\hat{\beta}_{LASSO} = arg\ min\left[\sum_{i=1}^{n}(Y_i - \beta_0 - \sum_{j=1}^{p} X_{ij}\beta_j)^2 + \lambda \sum_{j=1}^{p}|\beta_j|\right] \quad (1)$$

Elastic net equation is written instead of LASSO equation. The LASSO equation must be written. Where λ is a tuning parameter of penalty |βj|, is a l1 penalty that is obtained by penalizing the absolute coefficients of the variables included in the model. According to Fan and Li (2001), there were two main problems of LASSO. The first problem was the shrinkage procedure of LASSO causing biased estimates of the large coefficients with an unacceptable estimation risk. The second problem was the variable selection of LASSO being automatic because the l1 penalty is not differentiable since it is singular at the origin. Zou (2006) proved that the LASSO is not consistent in model selection under mild conditions. To overcome such problems of LASSO, Zou (2006) developed the adaptive LASSO. This type of LASSO enjoys the oracle properties. The LASSO gains the oracle properties thanks to the optimal weights.

Elastic net method proposed by Zou and Hastie (2005) to overcome the parameter bias of LASSO in the case of collinearity. The elastic net estimator is as follows;

$$\hat{\beta}_{(Elastic\ Net)} = arg\ min\left[\frac{1}{2n}\sum_{i=1}^{n}(Y_i - \beta_0 - \sum_{j=1}^{p} X_{ij}\beta_j)^2 + \lambda(\frac{1-\alpha}{2}\sum_{j=1}^{p}\beta_j^2 + \alpha\sum_{j=1}^{p}|\beta_j|)\right] \quad (2)$$

Where λ and α are the tuning parameter of ℓ_1 and ℓ_2 penalty, respectively. $|\beta_j|$ is ℓ_1 penalty, $|\beta^2_j|$ is the ℓ_2 penalty which is obtained by penalizing the squared coefficients of the variables included in the model. The elastic net method establish a regression model taking advantage of ℓ_2 and ℓ_1 penalty of ridge and LASSO. Thus, the method simultaneously can make automatic variable selection and continuous shrinkage, and it can select groups of correlated variables. Nevertheless, this method does not enjoy the oracle properties such as parameter selection stability and normality. As a result, a significant bias can occur in the elastic net estimators.

Zou and Zhang (2009) developed the adaptive elastic net method, which enjoys the oracle properties and calculates the adaptive weights utilizing the elastic net estimators to overcome the problems of the elastic net.

The adaptive elastic net is a combination of ℓ_2 and ℓ_1 penalty. When the estimator matrix is sparse or ill-conditioned, the adaptive elastic net regression provides variable selection consistency as well as parameter stability. In addition, the ℓ_2 penalty deals with the trouble effects of strong collinearity (Zou and Zhang, 2009). Therefore, this method outperforms the elastic net. The estimator of the adaptive elastic net regression is as follows;

$$\hat{\beta}_{\left(\substack{Adaptive\\ ElasticNet}\right)} = (1+\frac{\lambda_2}{n})[\ \underset{\beta}{\operatorname{argmin}}\left\|y - \sum_{j=1}^{p} x_j\beta_j\right\|^2 + \lambda_2\sum_{j=1}^{p}\beta_j^2 + \lambda_1^*\sum_{j=1}^{p}\hat{w}_j|\beta_j|]$$
$$\text{Subject to } \hat{w}_j = \frac{1}{\left(|\hat{\beta}_j^{(enet)}|\right)^{\gamma}},\ j = 1, \dots, p\ . \quad (3)$$

Where λ_2 represents the tuning parameter of ℓ_2 regulation, λ_1^* represents the tuning parameter of ℓ_1 regulation, $\hat{w}_j$ is adaptive weight obtained through elastic net coefficients, is a positive constant calculated by $\gamma = \frac{2v}{1-v}$ and $v = \lim_{n\to\infty}\frac{log(p)}{\log(n)}$. Tunning parameter of the model function is as follows;

$$P_\alpha = (1-\alpha)|\beta|_1 + \alpha|\beta|_2^2 = \lambda_2|\beta|_2^2 + \lambda_1\|\beta\|_1 \quad (4)$$

Here $\alpha = \frac{\lambda_2}{\lambda_1+\lambda_2}$ and $\alpha\in(0,1)$. After Zou and Zhang (2009)'s elastic net prediction weights, Jiratchayut and Bumrungsup (2015) set rescaled the elastic net estimator with to be three estimators. Here is a parameter given relations between shrinkage parameters. Adaptive elastic net regression, unlike conventional regression methods, enables superior results in the analysis as it applies a reduction procedure for both variable selection and minimum

variance estimators (Jiratchayut and Bumrungsup, 2015).

3. RESULTS

3.1. Data Set

The dataset was obtained from the TIMSS international database for 2015. The data used the 8th grade student background (BSGM6) questionnaires for Turkey and Singapore. According to the TIMSS 2015 survey, the number of participated students was 6079 and 6116 respectively for Turkey and Singapore. The irrelevant variables were excluded and applied the cleaning process through listwise deletion to handle with the missing data. The contents of TIMSS mathematics assessment are algebra, data and chance, geometry, number, and cognitive areas (knowing, applying, reasoning). The dependent variable was the average of these values.

3.2. Empirical Findings

The LASSO elastic net and adaptive elastic net regression methods (at three alpha level) which are the machine learning technique has been applied to Turkey and Singapore's 2015 TIMSS Survey datasets. All methods carried out in R software using packages msaenet for adaptive elastic net, glmnet for LASSO and elastic net. First, I divided the dataset into training and test datasets with a ratio of 80:20. The dataset of Turkey consists of 3340 students by 2672 training and 668 test data whereas Singapore has 3318 number of students with 2654 training and 664 test data. The training dataset was utilized to predict model parameters and hyperparameters. The test dataset was utilized to validate forecasting accuracy of the models with these parameters and hyperparameters. Prediction accuracy measures how close the forecasting values are to the data employed in the estimation except of sample datasets. It informs whether the parameters are optimally selected and whether the best model is constructed. The validation of the hyperparameters of this constructed best model is measured by using the test dataset. The error-based criteria which are the root mean square error (MSE), the mean absolute error (MAE), and R-squared were used for prediction of hyperparameter and validation. After the detection and validation of hyperparameters, the regression coefficients were estimated through the utilization of the adaptive elastic net methods for both data sets.

Following the study of Jiratchayut and Bumrungsup (2015), three different approaches were applied for the detection of the alpha values, [0.1, 0.5, 0.9], and then the weighting of the adaptive elastic net was utilized. Finally, the most appropriate alpha value was chosen based on the prediction accuracy.

Table 2. Prediction and Forecasting Accuracy Table

Country	*weight*	*Train Sample*			*Test Sample*		
		RMSE	*MAE*	*R-squared*	*RMSE*	*MAE*	*R-squared*
TR	Lasso	0.123201	0.098334	0.63	0.126347	0.100251	0.61
	Elastic Net	0.127758	0.102687	0.61	0.131681	0.104535	0.58
	Adaptive Elastic Net(0.1)	0.115433	0.092498	0.68	0.114224	0.091378	0.67
	Adaptive Elastic Net(0.5)	0.115394	0.092517	0.68	0.114215	0.091350	0.67
	Adaptive Elastic Net(0.9)	0.115388	0.092514	0.68	0.114209	0.091341	0.67
SGP	Lasso	0.093833	0.071983	0.44	0.093934	0.069866	0.46
	Elastic Net	0.097089	0.074330	0.40	0.097025	0.072925	0.42
	Adaptive Elastic Net(0.1)	0.082870	0.063779	0.57	0.088314	0.068796	0.47
	Adaptive Elastic Net(0.5)	0.082813	0.063776	0.58	0.088310	0.068748	0.47
	Adaptive Elastic Net(0.9)	0.082808	0.063775	0.58	0.088301	0.068748	0.47

Notes: (i) In the adaptive elastic net method, penalty parameters, λ and α were optained by k-fold cross validation; k was chosen as 10.

(ii) Adaptive elastic net results were obtained according to α=(0.1,0.5,0.9) values.

(iii) $RMSE = \sqrt{\frac{\sum_{i=1}^{n}(y_t-\hat{y}_t)^2}{n}}$, $MAE = \frac{\sum_{i=1}^{n}|y_t-\hat{y}_t|}{n}$, $R-squared = \frac{\sum_{i=1}^{n}(\hat{y}_t-\bar{y}_t)^2}{\sum_{i=1}^{n}(y_t-\bar{y}_t)^2}$

Table 2 shows the RMSE, MAE, and R-squared results based on errors obtained from training and test sample purposes for two countries and each methods. The RMSE, MAE and R-squared values of TR are [0.115388, 0.092514, 0.68] for training data and [0.11421, 0.09134, 0.67] for test data; the values of SGP are [0.082808, 0.063775, 0.58] for training data and [0.08830, 0.06875, 0.47] for test data. As presented in Table 2, the adaptive elastic net regression rescaled with an alpha level of [0.9] is the most accurate method for both countries.

According to the estimation results, for the model for Turkey, 60 non-zero coefficients were estimated from 98 variables by the adaptive elastic net method with the alpha level 0.9 whereas for the model for Singapore, 68 non-zero coefficients were estimated from the 100 variables by the method with the alpha level 0.9. The results of adaptive elastic net regression are presented in Table 3.

Table 3. Results of the Adaptive Elastic Net

			TR	SGP
Variable	**Definition**		**Adaptive Elastic Net(0.9)**	**Adaptive Elastic Net(0.9)**
ITSEX	Sex Of Students	(1 if female, otherwise 0)	-0.0116	-0.0090
BSBG03	Gen\Often Speak <Lang Of Test> At Home	1(always) to 4(Never)	-0.0266	0
BSBG04	Gen\Amount Of Books in Your Home	1(0-10) to 4(More than 200)	0.0149	0.0079
BSBG05	Gen\Digital information Devices	1(None) to 4(More than 10)	0.0050	0.0085
BSBG06A	Gen\Home Possess\Computer Tablet Own	(1 if yes, otherwise 0)	0	0.0048
BSBG06B	Gen\Home Possess\Computer Tablet Shared	(1 if yes, otherwise 0)	0.0304	0.0180
BSBG06C	Gen\Home Possess\Study Desk	(1 if yes, otherwise 0)	0.0058	0.0091
BSBG06E	Gen\Home Possess\internet Connection	(1 if yes, otherwise 0)	0	0.0291
BSBG06F	Gen\Home Possess\Own Mobile Phone	(1 if yes, otherwise 0)	0.0332	0
BSBG06G	Gen\Home Possess\Gaming System	(1 if yes, otherwise 0)	0	-0.0081
BSBG06H	Gen\Home Possess\<Country Specific>	(1 if yes, otherwise 0)	0.0074	0.0142
BSBG06I	Gen\Home Possess\<Country Specific>	(1 if yes, otherwise 0)	-0.006	0
BSBG06J	Gen\Home Possess\<Country Specific>	(1 if yes, otherwise 0)	0.0186	0.0221
BSBG06K	Gen\Home Possess\<Country Specific>	(1 if yes, otherwise 0)	0	-0.0162
BSBG07A	Gen\Highest Lvl Of Edu Of Mother	1(Primary/lowerSecondary/None) to 7(Postgraduate)	0.0043	0.0064
BSBG07B	Gen\Highest Lvl Of Edu Of Father	1(Primary/lowerSecondary/None) to 7(Postgraduate)	0.0072	0.0015
BSBG08	Gen\How Far İn Edu Do You Expect To Go	1(Lower secondary) to 6(Postgraduate)	0.0257	0.0209
BSBG09A	Gen\Mother Born İn <Country>	(1 if yes, otherwise 0)	0	-0.0080
BSBG09B	Gen\Father Born İn <Country>	(1 if yes, otherwise 0)	0.0282	-0.0028
BSBG10A	Gen\Born İn <Country>	(1 if yes, otherwise 0)	0	0.0045
BSBG11	Gen\About How Often Absent From School	1(Once a week or more) to 4(Never,Almost Never)	0.0235	0.03178
BSBG12	Gen\How Often Breakfast On School Days	1(Every Day) to 4(Never,Almost Never)	0	-0.0038
BSBG13A	Gen\How Often Use Computer Tablet\Home	1(Every day,almost every day) to 4(Never,Almost Never)	0.0089	0
BSBG13B	Gen\How Often Use Computer Tablet\School	1(Every day,almost every day) to 4(Never,Almost Never)	0.0044	0.0012
BSBG13C	Gen\How Often Use Computer Tablet\Other	1(Every day,almost every day) to 4(Never,Almost Never)	0.0033	0.0073
BSBG14A	Gen\internet Use\Access Textbooks	(1 if yes, otherwise 0)	-0.0020	0
BSBG14B	Gen\internet Use\Access Assignments	(1 if yes, otherwise 0)	-0.0180	0.0302
BSBG14C	Gen\internet Use\Collaborate With Classmates	(1 if yes, otherwise 0)	0	0.0338
BSBG14D	Gen\internet Use\Communicate With Teacher	(1 if yes, otherwise 0)	-0.0359	0.0039
BSBG14E	Gen\internet Use\Find info To Aid in Math	(1 if yes, otherwise 0)	-0.0055	-0.0108
BSBG14F	Gen\internet Use\Find info To Aid in Science	(1 if yes, otherwise 0)	-0.0127	0.0158
BSBG15A	Gen\Agree\Being in School	1(Agree a lot) to 4(Disagree a lot)	0.0314	0.0114
BSBG15B	Gen\Agree\Safe At School	1(Agree a lot) to 4(Disagree a lot)	0	-0.0066
BSBG15C	Gen\Agree\Belong At School	1(Agree a lot) to 4(Disagree a lot)	0.0033	0
BSBG15D	Gen\Agree\Like To See Classmates	1(Agree a lot) to 4(Disagree a lot)	0.0042	-0.0023
BSBG15E	Gen\Agree\Fair Teachers	1(Agree a lot) to 4(Disagree a lot)	-0.0194	0.0045
BSBG15F	Gen\Agree\Proud To Go To This School	1(Agree a lot) to 4(Disagree a lot)	0	-0.0085

BSBG15G	Gen\Agree\Learn A Lot	1(Agree a lot) to 4(Disagree a lot)	0	0.0019
BSBG16A	Gen\How Often\Made Fun Of	1(At least once a week) to 4(Never)	0	0.0022
BSBG16B	Gen\How Often\Left Out Of Games	1(At least once a week) to 4(Never)	0.0090	-0.0044
BSBG16C	Gen\How Often\Spread Lies About Me	1(At least once a week) to 4(Never)	0	0.0039
BSBG16D	Gen\How Often\Stole Sth From Me	1(At least once a week) to 4(Never)	0.0018	0.0091
BSBG16E	Gen\How Often\Hurt By Others	1(At least once a week) to 4(Never)	-0.0055	0
BSBG16H	Gen\How Often\Posted Embarrassing Things	1(At least once a week) to 4(Never)	0.0144	-0.0038
BSBG16I	Gen\How Often\Threatened	1(At least once a week) to 4(Never)	0	0.0070
BSBM17A	Math\Agree\Enjoy Learning Mathematics	1(Agree a lot) to 4(Disagree a lot)	0.0041	-0.0003
BSBM17B	Math\Agree\Wish Have Not To Study Math	1(Agree a lot) to 4(Disagree a lot)	-0.0095	0.0087
BSBM17C	Math\Agree\Math is Boring	1(Agree a lot) to 4(Disagree a lot)	0.0034	0
BSBM17D	Math\Agree\Learn interesting Things	1(Agree a lot) to 4(Disagree a lot)	0	1.41666E-05
BSBM17F	Math\Agree\Like Numbers	1(Agree a lot) to 4(Disagree a lot)	0.0107	0
BSBM17G	Math\Agree\Like Math Problems	1(Agree a lot) to 4(Disagree a lot)	-0.0081	-0.0100
BSBM17H	Math\Agree\Look Forward To Math Class	1(Agree a lot) to 4(Disagree a lot)	0.0198	0.0061
BSBM17I	Math\Agree\Favorite Subject	1(Agree a lot) to 4(Disagree a lot)	-0.0075	0
BSBM18A	Math\Agree\Teacher Expects To Do	1(Agree a lot) to 4(Disagree a lot)	-0.0139	0
BSBM18B	Math\Agree\Teacher is Easy To Understand	1(Agree a lot) to 4(Disagree a lot)	0	-0.0063
BSBM18C	Math\Agree\interested in What Tchr Says	1(Agree a lot) to 4(Disagree a lot)	-0.0065	0.0066
BSBM18D	Math\Agree\interesting Things To Do	1(Agree a lot) to 4(Disagree a lot)	0	0.0057
BSBM18E	Math\Agree\Teacher Clear Answers	1(Agree a lot) to 4(Disagree a lot)	-0.0048	0
BSBM18F	Math\Agree\Teacher Explains Good	1(Agree a lot) to 4(Disagree a lot)	0	-0.0016
BSBM18G	Math\Agree\Teacher Shows Learned	1(Agree a lot) to 4(Disagree a lot)	0.0098	0
BSBM18H	Math\Agree\Different Things To Help	1(Agree a lot) to 4(Disagree a lot)	0.0097	0.0032
BSBM18I	Math\Agree\Tells How To Do Better	1(Agree a lot) to 4(Disagree a lot)	0	0.0043
BSBM18J	Math\Agree\Teacher Listens	1(Agree a lot) to 4(Disagree a lot)	0	-0.0045
BSBM19A	Math\Agree\Usually Do Well in Math	1(Agree a lot) to 4(Disagree a lot)	-0.0314	-0.0092
BSBM19B	Math\Agree\Mathematics is More Difficult	1(Agree a lot) to 4(Disagree a lot)	0.0214	0
BSBM19C	Math\Agree\Mathematics Not My Strength	1(Agree a lot) to 4(Disagree a lot)	0.0147	0
BSBM19D	Math\Agree\Learn Quickly in Mathematics	1(Agree a lot) to 4(Disagree a lot)	-0.0081	-0.0060
BSBM19E	Math\Agree\Mat Makes Nervous	1(Agree a lot) to 4(Disagree a lot)	0.0119	0
BSBM19F	Math\Agree\Good At Working Out Problems	1(Agree a lot) to 4(Disagree a lot)	-0.0072	-0.007
BSBM19G	Math\Agree\i Am Good At Mathematics	1(Agree a lot) to 4(Disagree a lot)	-0.0046	0.0046
BSBM19H	Math\Agree\Mathematics Harder For Me	1(Agree a lot) to 4(Disagree a lot)	0.0086	0.0184
BSBM19I	Math\Agree\Mat Makes Confused	1(Agree a lot) to 4(Disagree a lot)	0.0048	0.0060
BSBM20A	Math\Agree\Mathematics Will Help Me	1(Agree a lot) to 4(Disagree a lot)	0.0079	0.0116
BSBM20B	Math\Agree\Need Mat To Learn Other Things	1(Agree a lot) to 4(Disagree a lot)	0.0066	-0.002
BSBM20D	Math\Agree\Need Mat To Get The Job i Want	1(Agree a lot) to 4(Disagree a lot)	0	0.0157
BSBM20F	Math\Agree\Get Ahead in The World	1(Agree a lot) to 4(Disagree a lot)	0	0.0069
BSBM20G	Math\Agree\More Job Opportunities	1(Agree a lot) to 4(Disagree a lot)	0	-0.0074
BSBM20H	Math\Agree\Parents Think Math important	1(Agree a lot) to 4(Disagree a lot)	-0.0149	-0.0092
BSBM20I	Math\Agree\important To Do Well in Math	1(Agree a lot) to 4(Disagree a lot)	-0.0055	-0.0059
BSBM25AA	Math\How Often Teacher Give YouHomework/Math	1(Every Day) to 5(Never)	0.01293	-0.0096
BSBM25BA	Math\How Many Minutes Spent On Homework/Math	1(No Math Homework) to 6(More than 90 minutes)	0.01032	0.0101
BSBM26AA	Math\Extra Lessons Last 12 Month\Mathematics	1(Yes, to excel in class) to 3(No)	0	-0.0187
BSBM26BA	Math\Extra Lessons How Many Month\Mathematics	1(Did not attend) to 4(More than 8 months)	0.01191	0
ITAC-COMM1	Special Accommodation\Achievement Session	(1 if yes, otherwise 0)		-0.0784
BSDM-LOWP	Mathematics Ach Too Low For Estimation	1(not too low), o(low)	0.19278	0.2607

4. DISCUSSION

The findings of the adaptive elastic net regression are classified as home resources, breakfast habits, gender, origin and language, information and communication technologies, communication with social environment, talented teachers, mathematics achievement, homeworks and extra lessons. These could be summarized as follows:

Home Resources

Amount of books at home (BSBG04), digital information devices (BSBG05) and study desk possession (BSBG06C) variables can be grouped as home education opportunities variables. According to the TIMSS 2015 national mathematics and science pre-report published by the Republic of Turkey Ministry of National Education, the 8th grade students who participated in the 2015 study, 7% of home education opportunities are "high", 54% are "middle" and 40% are low (Yıldırım et al. 2016). The results of this report also support the findings of this study. The success rate of 8th grade students increased as their home education opportunities increased. These variables are important factors on the TIMSS Mathematics achievement for both countries. Students with more home education resources (amount of books, digital information devices, computer tablet, and study desk and country specific home resources) performed better overall on TIMSS compared to others, and the correlations between TIMSS and the school achievement were stronger for students had much more home education resources possession. Moreover, living in special accommodation (ITACCOMM1) separately from the family had a negative effect on the TIMSS math success of Singaporean 8th grade students. This is an important result in terms of the effect of the family on student success in Singapore.

The findings for Turkey show some similarities to the results of the study by Kaleli-Yılmaz and Hanci (2016). They found a relationship with TIMSS and school grades and parents' educational level but they did not come up with a gender effect. However, my results show that the family education (BSBG07A and BSBG07B) were also found to have a great effect on student success for both countries. In fact, the children's success should depend on the country's education system, not on the family's education. As long as the Ministry of National Education could provide support for families who are not capable of educational support for their children, this leads to the success of generations ongoing.

Breakfast Habits

According to Adolphus et al. (2013) and Littlecott et al. (2015) eating breakfast has a positive effect on children's cognitive performance, especially in the areas of memory and attention. Lundqvist et al. (2019) found a positive association between breakfast consumption and academic achievement among children and adolescents. The breakfast (BSBG12) was also found to be a supporter factor on the TIMSS math scores of students in Singapore.

Gender

According to the adaptive elastic net results, the gender variable (ITSEX) plays an important role in determining student success for two countries. The girls' achievement scores are less than boys for both countries. Although girls have self-confidence, sense of belonging, motivation, and liking learning they have lagged behind in transforming them into success unlike boys (Polat and Madra, 2018). In addition, as mentioned in the UNESCO 2017's "Cracking the code: girls' and women's education in science, technology, engineering and mathematics (STEM)" book, girls STEM performance can be affected from the individual level (biological and psychological factors), family and peer-level, school level and societal level. The methods offered can be summarized as individual-level that differentiated perception between genders is biological factors such as brain structure and hormones, as well as psychological factors such as interest and motivation. As with other cognitive skills, these are changeable, can be affected by training and practices, and can be developed. If parents make enough effort for the progress of girls, it is easier for girls to overcome social, economic, and cultural barriers. The education policies can build girls' interest, self-confidence, and professional expectations in STEM. Media and social media supports are needed to challenge sexual discrimination in science and to direct girls to science. In addition, social media literacy lessons should be given for girls to better benefit from digital technology.

Origin and language

The birth place of mother and father (BSBG09A and BSBG09B) variables have positive sign contrast to student born in country (BSBG10A) variable in Singapore Model. Singapore is a multi-ethnic country. About 75% of Singapore's population is Chinese and nearly %25 of the population is Malay or Indian (Ginsburg et al. 2005). Although students were born in the country, their parents can be immigrants. Since Singapore has bilingual education strategy that includes mother tongue (Chinese, Malay, or Tamil), language differences are not a problem

on Singapore's TIMSS success. The father born in the country (BSBG09B) variable was selected in the model for Turkey. This finding was not surprising for Turkish students, because of majority (or almost all) of the students and their parents were born in Turkey. Although the students and their parents were born in Turkey, the country has multilingual and multicultural structure. This is because the country has been a migration route for centuries and has hosted many different civilizations. (Yılmaz and Şekerci 2016). In some parts of the country, the language spoken within a family is different from the official language of the country.

Information and Communication Technologies

The Singapore's technology-oriented education system, possession of information communication technology devices (BSBG06A, BSBG06B, BSBG06E, BSBG06F), play a very important role in increasing Mathematics TIMSS achievement of Singapore. While mobile phone does not affect student achievement in Singapore, it has been observed to be effective in Turkey. According to the results of 2015 Turkish Statistical Institute (TUİK) Household Information Technology Usage Survey, 96.8% of the households have mobile phones, 43.2% of the households have computer tablets or laptop, 25.2% of the households have desktop computer and regular internet user rate is 94.2% in the first quarter of 2015. These rates explain the reasons for the positive effect of mobile phones on the 8th grade TIMSS achievement in Turkey. Since internet usage is very common, internet connection (BSBG06E) has not been found to be a distinctive feature of success. The using the internet to collaboration with classmates (BSBG14C) is not a factor in mathematics 8th grade students' TIMSS achievement of Turkey but adjuvant for Singapore's. Güler et al. (2017) examined the internet usage aims of children between the ages of 6-15 are examined. They found that, the rate of "making voice or video calls was 7%. In contrast to this low rate, the 6-15 age children's rate of "using the internet for homework and learning" was 85%. I found that the TIMSS scores decrease as the usage of computer tablets increases at home, school or anywhere among the Turkish 8th grade students.

Accessing textbooks and assignments through the internet (BSBG14A, BSBG14B), communication with teacher (BSBG14D), finding info to aid in math and science (BSBG14E, BSBG14F) variables are the factors that decreased student success by the contrary of Singapore. In contrast, the using of the internet to find info to aid in math (BSBG14E) and to access textbooks (BSBG14A) are the factors that increased success. The using the internet to find info to aid in math (BSBG14E) variable has a negative effect on Singapore's mathematics TIMSS success like Turkey. Since the Singapore mathematics curriculum is not exhaustive, it allows the student to understand better in lessons, and students use technology to access textbooks. Students use ICT for practice because they get "math sense" at school. Besides, the using the internet to access textbooks (BSBG14A) is not a distinctive feature on success, because each student can access. Moreover, the TIMSS scores of students increase as the level of their education expectations (BSBG08) increase and absent days from the school (BSBG11) decrease.

Communication With Social Environment

The communication of students in school has an important role in their mental, social, and academic development. In contrast, when the results of "The sense of school belonging" items are examined, the results of my analysis support the results of the 2011 TIMSS study of Topçu et al. (2016). I found that there was a negative correlation between sense of school belonging (BSBG15C) and TIMSS mathematics achievement scores in Turkey. The like to see classmates (BSBG15D) variable also has a negative effect on TIMSS mathematics achievement for Turkey. Besides, I can conclude that students who like being at school (BSBG15A) perform worse than others in the TIMSS math exam for both countries. Students who do not like being in school have more time to study lessons instead of having fun. In order to give students "math sense" in Singapore, mathematics lesson contents are not prepared exhaustively for the basic concepts of mathematics are learned more easily (CIU 2008). This inference explains why the decrease in the opinion of "I learn a lot at school", which is among my results, causes an increase in Singapore's TIMSS math score.

According to TIMSS 2015 survey results, in Singapore, 36% of students are every month and 6% of students are every week exposed to student bullying. In Turkey, 26% of students are every month, 6% of them are every week suffered from student bullying (Mullis et al. 2016). Student bullying may affect the academic performance of bullied children. Akyüz (2014) has studied Mathematics Achievement in TIMSS 2011 for Turkey and Finland and has revealed that student bullying is a significant factor of the 2011 mathematics achievement of Turkey. In

my TIMSS models, made fun of (BSBG16A), spread lies about me (BSBG16C), and threatened (BSBG16I) are decreasing factor for only Singapore's TIMSS performance; stole sth. from me (BSBG16D) is also a decreasing factor for both countries. With the development of technology, cyberbullying has become very common among adolescents recently (Gimenez-Gualdo et al. 2018). The posted embarrassing things (BSBG16H) is an example of cyberbullying. The left out of games (BSBG16B) and the posted embarrassing things (BSBG16H) variables have a negative effect on Turkish students' scores unlike Singapore's.

Talented Teachers

As Nye et al. (2004) suggests, teachers play an important role in the students' success in academic life as well as in daily life. The teacher quality is high in Singapore. Teachers are provided with training, salary arrangement and reward support (Levent and Yazıcı 2014). All teachers are trained at Nanyang Technological University, National Institute of Education. All candidate teachers are selected through interview by participants of a responsible institution (OECD 2012). In Singapore, information communication technologies are integrated into the class atmosphere through pedagogic methods by these talented teachers. In addition, another purpose of teachers is to give students math sense and provide an easy understanding of education in the lessons. Extra lessons are also provided for students had low perception. Since the education system of Singapore is pedagogical and has structured on the technology equipment, the teachers may not need to do and say interesting things for students' success. The reason for the negative effect of variables on success maybe only the unsuccessful students need these methods in Singapore. Besides, "teachers whose expectations were not known by the students (BSBM18A)", "who were thought not to say interesting things by the students (BSBM18C)", "who cannot give clear answers to the student questions (BSBM18E)" had a negative effect on Turkish Students' TIMSS achievement.

Mathematics Achievement

In Singapore, teachers who can be understood easily (BSBM18B) and can listen to what the students say (BSBM18J) have a positive effect on student achievement. In contrast, teachers who do and say interesting things about lessons (BSBM18C, BSBM18D), do various things to help students learn (BSBM18H), give information about how the students should do better when they make a mistake (BSBM18I) have a significant negative effect. In the TIMSS 2015 8th grade survey, there are 9 variables for measuring student confidence in mathematics. These can be listed as usually do well in math (BSBM19A), mathematics is more difficult (BSBM19B), mathematics not my strength (BSBM19C), learn quickly in mathematics (BSBM19D), math makes me nervous (BSBM19E), good at working out problems (BSBM19F), I am good at mathematics (BSBM19G), mathematics harder for me (BSBM19H) and math makes confused (BSBM19I). Contrary to Çavdar (2015), the TIMSS 2011 study, according to the Wilson and Narayan (2016), Choi et al. (2012), Ertürk and Erdinç-Akan (2018) studies that have been investigated the continuous effect of mathematics on achievement, as students' confidence in mathematics increases, their success also increases. All variables except "I am good at mathematics (BSBM19G)" supported the result of the studies. The student's confidence in mathematics has an important positive effect on 8th grade TIMSS math achievement. However, if the opinion that the student is good at math is decreasing, Turkish TIMSS scores are also decreasing contrary to Singapore.

My finding supports the Lee's (2013) study results that have found the students who think that they are bad in mathematics in Asia are more successful, students who think that they are good in mathematics in Europe are more successful.

The value that the student gives to mathematics perception was evaluated by 7 selected variables in the Adaptive Elastic Net model. Arıkan et al. (2016), Yavuz et al. (2017) have not found any significant relationship between the value given by Turkish students to mathematics and students' mathematics achievement scores in the TIMSS exams survey in 2007 and 2011. When the effect of the variables was examined one by one, the similar results were also found in this study. On the other hand, in Singapore, the decreasing in the expectation that more job opportunities can be obtained utilizing mathematics (BSBM20G) causes a decreasing effect on student math achievement. The parents think Math is important (BSBM20H) and being good at math is important (BSBM20I) variables have an important role in TIMSS scores in both two countries. These findings also show the negative effect of decreasing family support and students' math self-confidence on students' achievement.

Compared to the total time, students in Singapore are getting more hours of Mathematics lessons than Turkish students (Bozkurt et al. 2019). The result is not surprising as trying out feedback or different learning methods during limited mathematics lesson hours can make students lagged behind the other 8th class students in basic mathematics topics.

Homework and Extra Lessons

In contrast to Singapore in Turkey, decreasing the frequency of math homework (BSBM25AA) given to the 8th grade students is a negative factor on achievement. Because of the homework given to students very often in Turkey, students may be bored, feel tired or exhausted. This may lead to diminishing the will to study, so their academic success may reduce. As stated by the Mullis et al. (2016) TIMSS 2015 report, when compared to the rates of the 8th grade students spending more than 3 hours per week, it was seen that Singapore (22% rate) overtaken Turkey (12% rate). The rates of both countries are above the OECD average. Although the increase in the hours spent on homework, (BSBM25BA) seems to increase success in both countries in my results, the reason for Singapore's superiority in TIMSS exams cannot be explained only with this. In Turkey, homework does not play an improvement role in students' cognitive abilities because these are often repetitions of knowledge and practices in the classroom in contrast to Singapore. The mathematics lessons are given theoretical in Singapore and lesson practices are given to students as homework. Students do their homework from electronic lesson contents all schools served that are accessible to every student. In this way, students improve their cognitive abilities through the homework that utilized the information given in the class.

The attendance frequency of the extra lessons (BSBM26BA) have been found a positive effective factor in success only in Turkey. In contrast, the extra lessons last 12 month (BSBM26AA) has a negative effect on TIMSS success of 8th grade students in Mathematics in Singapore. This result is not surprising for Singapore, where the mathematics is teaching in the class detailed and that the students only who have unsuccessful need extra lessons.

5. CONCLUSION AND SUGGESTIONS

The subset of the variables affecting the TIMSS scores was selected for Turkey and Singapore using adaptive elastic net regression, which is a machine learning method that enables superior results in the analysis as it applies a reduction procedure for both variable selection and minimum variance estimators. The findings show that there exists some differences regarding the selected variables affecting the TIMSS scores among two countries. These are reported below:

In Turkey, there is the children descent from different ethnic origins. Therefore, the difference between the language spoken at home and the language of the test is a problem for Turkey. As a solution, extra official language lessons can be given to students who have problems with Turkish or can be provided bilingual (English and mother tongue) education to students similar to Singapore.

Home education resources and especially books that are important for the education and development of children have also been an important factor in the TIMSS achievement of students. Encouraging students to gain reading habit can be an important strategy for increasing the TIMSS achievement of Turkey.

The high frequency of homework given to the students is not found as an effective way to reach high TIMSS scores in Turkey contrary to Singapore. As in Singapore, instead of given homework that repeats information in class, teaching contents in the class and giving homework for only practice can be a way to increase students' cognitive development and TIMSS success in Turkey.

Mathematics textbooks in Turkey are quite extensive. This reduces the student's interest in mathematics. The content of the lesson can be reduced and lesson content that improves students' cognitive abilities instead of lesson content based on memorizing can be prepared like the Singapore education system.

Singapore has a technology-oriented education system unlike Turkey, information-communication technologies play an important role in TIMSS success. Unfortunately, technology-oriented education is not enough in Turkey.

Training talented teachers also play an important role in Singapore's exam success. According to the 2015 TIMSS results, Singapore students are the world's best students in mathematics. The Ministry of Education Singapore trains educated teachers who can use the technology pedagogically in lessons. If Turkey wants to move to a technology-oriented education system, the government should firstly raise the quality of teachers. The quality of education is directly related to the qualifications of teachers.

Overall, the findings indicate that individual, institutional, socioeconomic factors as well as technological factors are effective in the educational performances of the countries. They also show that the technology-oriented education system with talented teachers, less homework, less extensive textbooks, and lessons that improving cognitive ability, home education resources are significant parameters to construct the education policies in Turkey for obtaining higher scores in the next TIMSS exams.

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