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Abstract

Do locally hired teachers benefit pupils' school achievements more than governmental employed teachers? In Republic of Kenya (below referred as Kenya), there are two types of teachers in public primary schools. One is those employed by the government and the other is those hired by the local school community, named "PTA teacher". Though locally hired teachers are in general less qualified in terms of educational background and paid substantially lower than that of governmentally employed teachers, past randomized experiment results show that the marginal product in terms of test score is positive and significant when pupils are taught by PTA teachers (Duflo et al. 2012, and Bold et al., 2013).

By using a nationally representative rich data set, with the Generalized propensity score matching method, the present study examines the effect of PTA teacher ratio (ratio of PTA teachers out of total number of teachers) on education outcome. The question of this study is "if PTA teachers have superior performance, proved by the Randomized Controlled trial in Kenya, should higher PTA teacher ratio in one school bring better educational outputs?". With the nationally representative dataset containing rich educational school inputs as well as individual pupils' background and household information, this paper estimates the dose response function of school average outcomes. Provided that government teachers' allocation and school selection by the parents can be an endogenous to pupils' school outcomes, this paper utilizes the generalized propensity score method by Hirano and Imbens (2004) which enable us to estimate the function of the continuous treatment effect, PTA teacher ratio. The result consistently shows that the PTA teacher ratio affects school outcomes nonlinearly.

JEL code: C30, C32
Keywords: Continuous treatment, Generalized propensity score, Program evaluation

† Corresponding author: Graduate School of Economics, Osaka University,
Address: 1-7, Machikaneyama, Toyonaka, Osaka, 560-0043, JAPAN,
E-mail address: qgp802wa@student.econ.osaka-u.ac.jp

1. Introduction

One of the significant improvements in education sector for the past two decades is drastic increase in enrollment of primary school pupils in developing countries. According to the UNESCO Institute of Statistics (UIS) reports, the out of school children in the world has greatly reduced from 100 million to 58 million as of 2012 since 2000 (UIS, 2014)[1]. At the same time, facing the sudden increase in enrollment of primary school pupils, supply side was not kept up with the pace, especially supply of teachers. After the Free Primary Education policy, how to supply school teachers has become one of the substantial topics in education sector. Within the limited budget, various developing countries were to introduce the system of "contract teachers". For example, in 11 west African countries, on average, nearly 50% of primary school teachers were contract teachers (Bourdon et al., 2007). In Kenya, though there is no official figure for the number of PTA teachers, it is on average 20% of teachers in schools employed by the PTA (Alice Muthoni, 2010, Uwezo Kenya, 2010)[2].

The characteristics of contract teachers are with shorter term contract and in general with lower qualifications than that of governmentally hired teachers (Duthilleul 2005). For example, half of the PTA teachers in Kenya have a Primary 1 (P1) certificate as their highest qualifications, whereas 20% had no formal qualifications. On the other hand, 79% of the governmentally employed teachers had P1 qualifications (Alice Muthoni, 2010). In terms of the cost, the PTA teachers are paid substantially lower, which is one forth of that of governmentally employed teachers (Duflo et al., 2012, Alice Muthoni, 2010).

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[1] Substantial reduction was found in south and west part of Asia from 2000 to 2012 and the half of the entire out of children as of 2012 is concentrated in sub-Sahara Africa. A significant decline in the number of out of school children is mainly due to the "Free Primary Education" policy introduction (UIS, 2014).
http://www.uis.unesco.org/FactSheets/Documents/fs-28-out-of-school-children-en.pdf

[2] This figure varies slightly with sources. One report approximates 17.5% of teachers are paid by the PTA (Alice Muthoni, 2010) and the other repot says on average, 1 out of 5 teachers are employed by the PTA (Uwezo Kenya, 2010).

While it is obvious that hiring PTA teachers is less costly, past experiments show that performance is not lower than the government employed teachers. The performance of these contract teachers is empirically studied, based both on the randomized experiment and by observational data (Atherton and Kingdon 2015, Bold et al., 2013, Muralidharan and Sundaraman 2013, Duflo et al., 2012, Bourdon et al., 2010, Duthilleul 2005, and Vegas and De Laat 2003). Experimental evidence infers that PTA teachers cause better educational outcomes measured by test score in Kenya (Duflo et al.,2012) . In India, marginal effect of randomly allocating local teacher raises test score with statistical significance. As the experimental evidence in Kenya and India, it shows that PTA teacher is as good as or better than the government employed teachers. Then, if PTA teachers are superior in teaching, should all teachers be replaced by PTA teachers?. The more PTA teachers in one school would bring better educational outcomes on average?". The cost of hiring PTA teachers is substantially lower than government teachers, the question is important to be answered. Provided that PTA teachers' allocation within a school could be an endogenous to pupils' school outcomes, this paper is to investigate the aggregated effect of PTA teachers, that is, the ratio of PTA teachers (the number of PTA teachers out of total teachers in one school) on pupils' school outcomes.

2. Preceding Studies

Regardless of highly important policy implications, publications solely dealing with locally hired "contract teacher" effect is scarce (Atherton and Kingdon 2015, Bold et al., 2013, Muralidharan and Sundaraman 2013, Duflo et al., 2012, Bourdon et al., 2010, Duthilleul 2005, and Vegas and De Laat 2003). For the causal inference, randomized controlled experiments were conducted in two countries and both indicate that PTA teachers' effect on school outcomes is positive and significant[3]. On the other hand, in observational studies, Atherton and Kingdon (2010)

[3] Duflo et al. (2012) has shown that the pupils taught by PTA teachers have significantly increased test scores, compared to those taught by government hired teachers. Bold et al. (2013) also shows the result of randomization controlled trials in Kenya that the test scores of pupils taught by the PTA teachers have significantly increased when the program was implemented by an International NGOs. Muralidharan and Sundaraman (2013) have showed that the randomly assigned contract teachers in India contribute the increase of test scores,

reports that by school fixed estimation method, contract teachers in North India are no less effective on school test scores than regular teachers. On the other hand, Vegas and De Laat (2003) show that contract teacher performance is systematically underperformed, using samples from Togo, while Bourdon, J. et al. (2010) shows that, by using observational data for Niger, Togo and Mali with nonparametric quantile regression estimation, the average treatment effect as well as the effect on a certain quantile are not consistently positive among three countries.

In this way, while the experimental result shows that the impact of PTA teacher deployment raises test score, observational studies have the mixed result. The contribution that this paper makes on the past literature is as follows: First, this study is to focus on the effect of "existing" PTA teachers on pupils' school outcome, not to measure the marginal effect of "newly" hired or "randomly" deployed teacher. It is worth noting that there is significant difference between newly deployed teacher by the experiment and existing PTA teachers regularly paid by school communities. The nature of existing PTA teachers is largely differed in the contract and payment scheme from the one of experiment deployed teachers, which would greatly affect working motivation and effort level of teachers. As one forth of total teachers are existing PTA teachers in Kenya, the nature of the contract and payment scheme would greatly affect the working incentive of teachers. For this reason, the present study uses the observational data.

For the use of observational data, obstacles exist in identification due to two types of unobserved heterogeneity which affect the school outcomes. One is the unobserved heterogeneity among schools and the other is the unobserved heterogeneity within a school. For the former heterogeneity, for example, government prioritizes in allocating teachers to schools where pupils with higher test scores are resident in and parents who are aware of school outcomes might self-select schools with less PTA

through reducing the PTR (pupil teacher ratio). The result is that the effect of PTR reduction by contract teachers is not less effective to the test scores as reduction by regular teacher.

teachers. The identification strategy of this paper must rely on the assumption that the selection into schools with different PTA teacher ratio is random, conditional on the covariates. To sufficiently remove the heterogeneity among schools with different PTA teacher ratio, this paper uses one of the largest dataset existing in East African countries, which contains various educational inputs for schools and household levels. The specification of propensity score does include the 23 covariates and 157 district level dummies so that the unobserved heterogeneity between different PTA teacher ratio schools would be removed. By putting the conditional independence assumption that school average test scores are independent from the PTA teacher ratio conditioned on the rich covariates, the paper identify the treatment effect on test scores. As the propensity score matching method (Rosenbaum and Rubin, 1983) is often utilized in the empirical works, the paper uses the extended propensity score method by Hirano and Imbens (2004) for the case that treatment is continuous. Our treatment, PTA teacher ratio does not take binary value but takes continuous values. In order to estimate the continuous treatment effect, the extended propensity score method is suggested (Imbens, 2000; Hirano and Imbens, 2004; Imai and van Dyk, 2004). By using the framework of extended propensity score method, this paper estimates the function of different treatment effect.

For the latter unobserved heterogeneity is within a school; for example, the assignment of PTA or TSC teachers is not presumably random and pupils might be systematically sorted into particular type of teachers without being observed. If TSC teachers are systematically assigned to higher score pupils, then the effect of PTA teacher is estimated downward. Even in the case of randomized experiment, when there is unobserved sorting process of pupils into different type of teachers (Bold et al., 2013), it becomes serious obstacle to the identification, explained in detailed by Muralidharan and Sundaraman (2013). In order to avoid the unobserved heterogeneity within a school, the present study focuses on the school level aggregated variable, the ratio of PTA teacher.

The second contribution is that the present study uses observations from geographically broad area with larger sample size. As for the experimental studies, two experiments were conducted in Kenya. One is in 140 primary schools in Western province and the other is in 192 schools in eight provinces (Duflo et al., 2012 and Bold et al., 2013), while for India, the sample was taken from 200 primary schools in one state (Muralidharan and Sundaraman 2013). The present study uses the nationally representing dataset containing 4,789 primary schools in all eight provinces[4]. Broader geographical coverage is preferred, since the heterogeneity of region is not ignorable. From this respect, the present paper contributes the past literature to confirm whether the estimated result is still valid even considering the geographical diversity.

3. Characteristics of Teachers in Public Primary Schools in Kenya

Present data does not have variables of characteristics of teachers such as age, years of education and experiences; however this section qualitatively describes the differences in general between the PTA and TSC teachers.

i) The employment of TSC teachers

As for the hiring and firing authority for TSC teachers, it is highly concentrated in the institutions called the Teacher Service Commission (TSC), delegated from the Ministry of Education Science and Technology (MoEST). In order for teachers to be certified by the TSC, one needs to acquire academic qualifications, ranging from the graduates of primary schools to Diploma. If non-graduate wishes to be a TSC certified teacher, they need to acquire a relevant degree or qualification from a recognized institution (UNESCO 2010). There are 25 public and 8 private colleges for training primary school teachers. Once they become certified TSC teachers because of the protective laws and union, it is unlikely to get fired (Duflo et al., 2012, Glewwe et al., 2010). On the other hand, PTA teachers are hired by the school community, parents and other school members such as headmasters. With scarce

[4] In the estimation, we use the sample restricted for schools with positive value of PTA teacher ratio. Hence, the total effective sample size is reduced to 3778 primary schools for 4th grade pupils, 3728 schools for 3rd and 3706 schools for 2nd.

qualitative information, it is often the case that PTA teachers' contract is annually renewable based on their performance.

ii) Monitoring on teachers

According to the laws and regulations of governmental monitoring policies, the work of government teachers is principally monitored by the District of Education Office (DEO)[5]. However, as qualitative studies explained, due to the large number of schools in one district, district education officers are lack of resources in mobilizing the monitoring school teachers (Omuga Thomas 2009, James Kariuki 2010, John Ogamba et al., 2013). For example, it is articulated that the "comprehensive standard assessment of all educational institutions be carried out by external Quality Assurance and Standards Officers (QASOs) at least once every term for primary schools" (James Kariuki, 2010)[6]. However, the table [1] shows merely 39% of the entire visits are confirmed by the headmaster during the term from January to March 2012. The table [1] shows the number and percentage of schools that answers how many months have passed since the previous Quality Assurance Officer visit[7]. In Kenya, there is a trimester system. The first term starts from January to March, the second from May to July and the last term starts from September to November. Although the regulation articulates the assurance officer must visit schools at least once in the term, 61% visits were made before January 2012, including 30% of missing information. When the previous term from September to November in 2011 included, it becomes 53% of the total officers' visit. The rest of nearly half of the visits were either done before August of 2011, which is two terms before the surveyed or unknown about when the inspections made.

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[5] In Kenya, country is divided into eight administrative regions (known as provinces) where each province has a Provincial Director of Education Office. In each province, there are districts, and in total 158 districts exist in the entire land and District of Education Office is (DEO) in charge of the monitoring of schools.

[6] The department of Quality Assurance and Standards (DQAS) was established in 2004, and its' mandate of this department is to ensure quality and standards in Kenya with the vision of "to provide quality assurance feedback to all educational institutions in Kenya." The Ministry of Education service charter (2009) and the DOAS circular 2/1A/Vol.II/86 of 2009 states the frequency of the external quality assurance (James Kariuki, 2010).

[7] Out of 4,234 schools that 2012 dataset contains, the effective answers are from 2,968 schools and 29.9% of schools have missing information.

Table [1]

Not only has the monitoring from the government, but also from the school community on TSC teachers become less since the introduction of the FPE (Free Primary Education) policy in 2003. Qualitative studies explain that before the policy, school communities were in charge of collecting school fees from parents and were entitled to decide how to spend the collected money. In that time, teachers were obliged to be accountable to payers, that is, parents and school community. However after introducing the FPE (Free Primary Education) policy, schools need to be more accountable to the District of Education Office as well as to the Central Government which decides the allocation of the capitation fund (Sasaoka et al. 2007). In this way, while the Free Primary Education has succeeded in assisting low income parents to send their children to school, however it happened to deprive the interest of parents to manage schools or incentive to monitor schools (Sawamura 2004a).

iii) Wage payment scheme

In addition to the employment and monitoring teachers, the determination of wage level is clearly different between two teachers. In developing countries, salaries and promotion of civil servants are likely to be decided by educational qualifications and seniority, with less scope of performance (Chaudhury et al. 2006). In Kenya, the wage for TSC teachers is determined by education history, not by their performance (Sawamura 2004b). As for PTA teachers, although the wage level of PTA teacher depends on schools, it is determined by the school local community who can directly verify the performance of teachers. The amount of wage for PTA teachers is substantially lower than that of TSC teachers. One report indicates that the average payment for PTA teachers is 4,151 Kenya Shillings,

which is one fourth of the average salary 19,372 Kenya Shillings of the TSC teachers (Alice Muthoni, 2010)[8].

4. Data

This paper uses dataset of UWEZO Kenya, a part of Twaweza, "an independent East African initiative" (UWEZO East Africa 2012), which conducted one of the largest national assessments in three eastern African countries for individual, school and local community. The annual national assessment survey was conducted in three countries, namely Kenya, Uganda, and Tanzania, to assess the basic competency of numeracy and literacy for children aged from six to sixteen. For the 2012 assessment in three east African countries, 350,000 children in over 150,000 households were tested in ability of tasks at the Standard 2 level (UWEZO East Africa 2012). Specifically in Kenya, 2012 UWEZO annual assessment covers 156 districts out of 158 (census) districts, which becomes 153,900 children assessed from 90,820 households, and 4,543 primary schools, that is, 20 percent of Kenya public primary schools surveyed at the same time so that surveyed pupils and household information as well as school information are merged at one dataset (UWEZO Kenya 2012).

Sampling methodology is based on the Census frame and the district is the main stratum[9]. Inside the district, there are 30 villages randomly selected and at least one public primary school per village is included. Within a village, 20 households are randomly selected and for the selection, it does not matter whether their children are attending the surveyed schools or not. All children are tested in their household environment and no tests are examined at their schools, hence children both attending and not attending schools are included.

There were three rounds of the national annual assessments in Kenya since UWEZO started to conduct survey in 2009. The geographical coverage has been expanded since 2009 as table [2] shows in detailed. The first round was in 2009 (70 districts covered), the second in 2011 (124 districts covered) and the third round was conducted in 2012 (156 districts covered out of the 158). Per district, it is a rotational panel with 10 villages newly replaced each year and 20 villages are remained. As for the schools, the remained 20 primary schools per district may or may not be changed for the following

[8] It slightly varies from different sources. Duflo et al. (2012) reports the wage for PTA teachers as of 2004 is in the rage of 2000 Kenyan shilling, while that of the average civil service teacher is US$ 120 per month plus benefits and allowance (Duflo et al., 2012).

[9] The detailed sampling methodology is written in the report available from the website (Standard Manual, Uwezo East Africa at Twaweza, Kenya).

year. Hence, though 20 villages are overlapped for two consecutive years, those 20 primary schools per district are not necessarily paneled. In this way, the number of overlapped effective schools from year 2011 to 2012 is small, in number 372 schools available in dataset[10]. Therefore, the present study does not apply the panel data analysis; rather the pooled data of two consecutive years and our unit of observations is at school level[11]. The variables included in estimations are as follows;

Table [2]

1) Independent Variables

Subjects of Swahili, English and Numeracy were scored at the time of household survey. Score of Swahili and English is rated from 1 to 5 while Numeracy is rated from 1 to 8[12]. Following variables are selected as controlling covariates, based on past studies of education production literature.

2) Class size, Pupil Teacher Ratio (PTR) and PTA teacher ratio variables

Since PTA teachers are often hired by school community to compensate the shortage of deployed government teachers (TSC teachers), without controlling the effect of shortage of teachers and pupil teacher ratio, PTA teacher ratio is only to capture the effect of large class size or large number of pupils per one teacher. To control the effect, pupil teacher ratio (PTR) and class size are included. As those above variables are skewed to the right, they are converted to logarithm and used in the estimation.

3) Household and Pupil Variables

Traditionally, the education production function literature assumes that the educational achievement is determined by the supply side such as school qualities or educational inputs and the demand side such as household characteristics. As for the demand side, it is assumed that the household takes the utility

[10] This is the number of primary schools which are overlapped from 2011 to 2012 and pupils grade below 4 attend. Some schools do not have any children grade below 4, hence the number of overlapped schools becomes smaller.

[11] The detailed effective samples selection process is in table in Appendix A. In the dataset, those attending the surveyed schools and grade lower than 4 are 35,642 for 2011 and 39,681 for 2012. Due to number of missing values in covariates, the effective samples for 2011 and 2012 pooled dataset become 47,812. The subsample of grade below 4 is somehow arbitrary, hence specifications based on the subsample of pupils grade above 5 and below 8 are shown in appendix B. Furthermore, the estimate based on the subsample with missing information drastically increases the sample size. The estimation with missing dummies yields qualitatively similar result and available from the author.

[12] The level of score rate in each subject is as follows: As for Swahili and English, children can read 1. Nothing, 2. Letter, 3. Words, 4. Paragraph, and 5. Story. As for Numeracy, children can do 1. Nothing, 2. count 1-9, 3. count 10-99, 4. count greater than 99, 5. calculate addition, 6. calculate subtraction, 7. calculate multiplication, and 8. calculate division.

maximizing behavior in choosing the optimal investment amount in children subject to the budget constraint. Hence, as proxies for wealth of a household, the asset variables were used, such as type of house wall and possession of telephone. Also, the literature finds that there might be a resource allocation issue about who to be invested most if the number of siblings is large. There is no variable for the number of siblings; however as the proxy variable, total number of household members is used to control the effect of resource competition.

In terms of unobserved ability of children, though not possible to totally control the effect, there are variables to partially control the unobserved. The effect of parents' education attainment is controlled by years of education for mother and father, which can directly affect unobserved ability of children. In order to control parents' preference over children education, the variable whether parents pay tuition or extra fee to school is included. As for pupil characteristics, variables included are age and their school grade. The older they are, it becomes easier to take high score, since the test level is set for Standard grade two level. Pupils are aged from three to sixteen and grade from one to fourteen. Primary school pupils are from age five and grade one to grade eighth. Each age and grade category dummy is included for the fixed effect. To control the physical health, the number of meal in one day that pupil can take is also controlled.

4) School Input Variables

In the early study of education production function estimation, Heyneman and Loxley (1983) explained that "the poorer the national setting in economic terms, the more powerful this (school inputs and teacher quality) effect appears to be". Since this "H-L effect" has been widely recognized and supported by several empirical results, this paper also controls the supply side information, including two variables for school inputs, in addition to PTR and class size. 1) Dummy variable if school has learning supplement materials or not. 2) Dummy variable if school is fenced or not, since the security in some areas is remained fragile after the large scale of post-election violence in 2007 December. While there are various types of educational input variables available in UWEZO Kenya 2012 and 2011 dataset, after most variables were tried to be included, however the coefficient of PTA teacher ratio is not largely affected.

5) Village and District Variables

It is often pointed out that there exist large disparities in terms of educational input between regions in Kenya. There are eight administrative regions in Kenya called Provinces and in each Province, there

are countless tribes and ethnic minorities live. It is rationally assumed that the cultural intensity affects the behavior of households and hence affects education attainment. In order to control the geographical characteristics and ethnic diversity, 157 district dummy variables are added for the district fixed effect. As for village characteristics where the school is located, the dummy variable of existence of paved roads and existence of electricity infrastructure are added.

5. Summary statistics and common support condition

Table [3.1] shows the summary statistics for the pupils in grade four before imposing the common support condition. Due to the limited space, the summary statistics for pupils in grade three and two is in appendix. To implement the propensity score method, it requires that there are sufficient number of schools which overlap the propensity score. It is because that propensity score matching relies on the assumption conditioned on the propensity score, the treatment is random to the outcome. Therefore, even those schools with different treatment levels, the generalized propensity score of estimation sample is sufficiently overlapped.

Following the literature (Flores et al. 2012, Kluve et al. 2012), we divide the treatment level into quantile groups (25, 50, 75 and 100 percentile) and estimate the generalized propensity score using the medium value of each quantile group. In general, in order to examine the overlapping condition for quantile group "q", we estimate the generalized propensity score $\hat{R}_i^q$ using the representative treatment value of the "q" group. In this paper, we use the medium value as the representative value of the group. Table 3.1 shows each quantile medium and mean value of the treatment and number of observations. As Flores et al. (2012) shows, the common support for quantile groups "q" is defined as follows. For example, how the common support condition imposed in the first quantile group is that minimum value of the estimated propensity score $\hat{R}_i^q$ must be greater than the minimum value of the rest of propensity score $\hat{R}_j^q$, while the maxim value of the estimated propensity score $\hat{R}_i^q$ should be smaller than the maximum value of the rest of propensity score $\hat{R}_j^q$. Based on this definition, the effective sample size is reduced as table 3.2. Figure 1 shows the distribution of generalized propensity score after imposing the common support restriction and before[13].

$$CS_q = \left\{ i: \hat{R}_i^q \in \left[max\left\{ min_{\{j:Q_j=q\}} \hat{R}_j^q,\ min_{\{j:Q_j\neq q\}} \hat{R}_j^q \right\}, min\left\{ max_{\{j:Q_j=q\}} \hat{R}_j^q,\ max_{\{j:Q_j\neq q\}} \hat{R}_j^q \right\} \right] \right\}$$

Table [3]

[13] For the brevity, the histograms for the grade 3 and 2 samples are not shown. The shape is similar to the one of grade 4 school sample. It is available from author upon the request.

Table [3.1]

Table [3.2]

Figure 1

6. Identification Strategy

6.1 Estimation of the propensity score

At first, the generalized propensity score is estimated by modeling the conditional distribution of treatment variable. Instead of putting the specific assumption of modeling of treatment variable, the paper uses more flexible modeling by the generalized linear models (McCullagh and Nelder, 1989). The generalized linear models for treatment variable T_i is unknown function "g" of the conditional expectation of treatment variable T_i given covariates X_i is linear combination of covariates with vector coefficients γ.

$$g[E(T_i|X_i)] = X_i\gamma$$

There are various modeling available by choosing the distribution function F as well as the functional form g. By comparing the model fitting, this paper uses the log-normal specification applied, based on the Akaike information criteria. The estimated coefficients vector is shown in table [4.1].

$$log(T_i|X_i) \sim N\{X_i\gamma, \sigma^2\}$$

As the definition of the generalized propensity score, the conditional density distribution of the treatment variable given covariates is as follows:

$$r(t, x) = f_{T|X}(t|X = x)$$

Accordingly, the probability density function for the actual treatment level T_i for the school i is estimated as follows.

$$\hat{R}_i(T_i, X_i) = \frac{1}{\sqrt{2\pi\hat{\sigma}^2}} exp\left\{-\frac{\left(T_i - e^{X_i\hat{\gamma}}\right)^2}{2\hat{\sigma}^2}\right\}$$

For the given treatment level "t", we also define the random variable $\hat{R}_i^{\,t} = r(t, X_i)$.

6.2 Balancing property of the propensity score

The role of propensity score is to balance the difference between those schools in a certain treatment level and those that are not in the same treatment level. To articulate in formula, given the certain treatment value of "t", the observed covariates are independent from whether it takes the value of "t" or not, conditioned on the propensity score given the treatment level "t".

$$X_i \perp 1\{T_i = t\}|r(t, X_i)$$

To confirm this balancing property of the propensity score satisfied, the literature has suggested number of ways. Hirano and Imbens (2004) suggest 'blocking on the score' and divide the sample into three different groups according to the distribution of treatment level. This paper uses the blocking on the score method and treatment level is divided into three groups as follows.

1) $\{0 < PTA\ ratio \leq 16\}$
2) $\{16 < PTA\ ratio \leq 26\}$
3) $\{26 < PTA\ ratio \leq 100\}$

In each group, taking the mean value as the representative value of the group, the generalized propensity score is estimated $\hat{R}_i^{\ t} = r(t, X_i)$, given the mean level of the treatment level. This estimated propensity score is divided into five intervals (20, 40, 60, 80, 99 percentile) and each interval, it is confirmed whether the covariates are well balanced or not among the different groups. For example, if the mean value of the treatment in 1) is 10 percent, using the value of 10 percent, the propensity score is estimated and divided into 5 intervals. The covariates should be balanced in the same interval, regardless of the fact the school belongs to the group 1) or to the other two groups. More concretely, this blocking on the score method is to examine whether the mean of the covariates are not statistically different each other as long as they are similar in generalized propensity score value.

Table [4.2] shows that compared to the covariates without conditioning on the propensity score, the balancing property is mostly satisfied for those conditioned. For example, when we compare the first treatment level (PTA teacher ratio is below 16 percent) with the rest of the schools, the mean of all covariates except 5 out of 23 variables are significantly different. At the same time, when we compare the last treatment interval group (PTA teacher ratio is over 26 percent), covariates except 7 are significantly different from zero. In this way, we find that without conditioning the propensity score, mean of each covariate does differ between the treatment levels. However, once we conditioned on the propensity score, no statistical significant difference is observed between treatment levels.

7. Estimation result for the dose response function

After estimated the generalized propensity score $\hat{R}_i(T_i, X_i)$ with the actual treatment value T_i, the school outcome is modeled as the linear function of treatment value as well as the estimated propensity score as follows. As emphasized by the Hirano and Imbens (2004), the estimated

coefficient vectors $\hat{\alpha}$ does not have any interpretation of causal effect of treatment on outcome variable.

$$E[Y_i|T_i, R_i] = \alpha_o + \alpha_1 T_i + \alpha_2 T_i^2 + \alpha_3 R_i + \alpha_4 R_i^2 + \alpha_5 R_i * T_i$$

By storing the coefficient vectors, to estimate the dose response function at the particular level of the treatment "t", the conditional expectation is averaged over the generalized propensity score for the fixed value of "t", $r(t, X_i)$. Therefore, for the given treatment level "t", the estimated average potential outcome is formulated as follows.

$$\widehat{E[Y_i(t)]} = \frac{1}{N}\sum_{i=1}^{N}\left(\widehat{\alpha_o} + \widehat{\alpha_1}t + \widehat{\alpha_2}t^2 + \widehat{\alpha_3}\widehat{R_{i,t}} + \widehat{\alpha_4}\widehat{R_{i,t}^2} + \widehat{\alpha_5}\widehat{R_{i,t}} * t\right)$$

7.1 The Does response function (DRF) estimation

The DRF is estimated at each percent point of PTA teacher ratio for three subjects, Numeracy, English and Swahili. The scale of Numeracy is ranged from 1 to 8 point, while scores of English and Swahili are ranged from 1 to 5. Looking at the estimated DRF for pupils in Figure 2, 3, and 4, it is apparent that the PTA teacher ratio is not only nonlinear to the school average test score for three subjects, but each subject has different percent point that generates the lowest test score. For example, the score of Numeracy for grade 4 pupils is lowest around 60 percent PTA teacher ratio, while, after reaching the lowest test score around 30 percent, English and Swahili subject start to raise the test score as PTA teacher ratio increases. As for the grade three, the test score of Numeracy subject is highest around 10 percent and goes down to the lowest at the point of 46 to 52 percent. The Numeracy test score starts to recover above 55 percent of ratio. In the grade two pupils, it is more obvious that test score is nonlinearly affected by the PTA teacher ratio. As for the Numeracy, there are two peaks observed; the first peak is at 10 to 20 percent and the second peak is from 70 to 80 percent. Both scores in grade three and grade two show that Swahili test score is overall higher than the English score and estimated response function shape is similar, the score difference between English and Swahili is smaller in grade two pupils.

7.2 Regional heterogeneity

As the past literature of randomized controlled trials has proved that the positive effect on test score of pupils by PTA teachers in Western province in Kenya (Duflo et al. 2012), the present paper shows the heterogeneity of 7 regions in Kenya. The figures 5 to 11 show the estimated school average outcome

response function of PTA teacher ratio at each percent point from 1 to 100 percent. The first obvious evidence is that it is heterogeneous among regions in terms of the shapes. For example, the mean and medium largely differ each other and the number of peaks differs among regions.

8. Interpretation and Policy Implication and further studies

The empirical results of dose response function are to show that treatment variable, that is, PTA teacher ratio nonlinearly affects the school outcome of pupils. This is intuitively reasonable result that the schools with 90 percent of PTA teacher are not the same effect on the schools with 10 percent of PTA teacher. This is the main contribution of this paper. Thought the existing literature of randomized controlled trials has found the PTA teacher brings positive and statistical significant effect on school outcomes, this paper shows that the causal effect on school outcomes differs at each treatment percent. While the estimation of the derivatives of dose response function and the statistical significance of them is required, the discussion should be opened to the level of the treatment.

References

Banerjee, Abhijit, Rukmini Banerji, Esther Duflo, Rachel Glennerster, and Stuti Khemani (2010).“Pitfalls of Participatory Programs: Evidence from a Randomized Evaluation in Education in India,” *American Economic Journal: Economic Policy*. 2(1): 1-30.

Banerjee, Abhijit, Shawn Cole, Esther Duflo and Leigh Linden (2007). “Remedying Education: Evidence from Two Randomized Experiments in India.” *Quarterly Journal of Economics*, 122, No. 3, 1235-1264.

Banerjee, A. and E. Duflo (2006): Addressing Absence, *Journal of Economic Perspectives*, Vol. 20, No. 1, 117-132.

Bishop, J. and L. Wosmann (2004): Institutional Effects in a Simple Model of Educational Production, Education Economics Vol. 12, No.1, 17-38.

Bjorkman, Martina, and Jakob Svensson. 2009. “Power to the People: Evidence from a Randomized Field Experiment on Community-Based Monitoring in Uganda.” *Quarterly Journal of Economics*, 124(2): 735–69.

Bold, Tessa, Mwangi Kimenyi, Germano Mwabu, Alice Ng'ang'a and Justin Sandefur (2012). “Pitfalls of Scaling-up Proven Education Interventions: Evidence from an RCT in Kenya”. Work in progress.

Bourdon, J., M. Frolich, and K.Michaelowa (2006). "Broadening Access to Primary Education: Contract Teacher Programs and Their Impact on Education Outcomes in Africa – an Econometric Evaluation for Niger," in *Pro-Poor Growth: Issues, Policies, and Evidence*, ed. by L. Menkhoff. Berlin: Duncker & Humblot, 117-149.

Bourdon, J., M. Frolich, and K. Michaelowa, (2007), "Teacher Shortages, Teacher Contracts and their Impact on Education in Africa," Paper No. 2007-20, Department of Economics, University of St. Gallen, St. Gallen.

Chaudhury, Nazmul, Jeffrey Hammer, Michael Kremer, Karthik Muralidharan, and F. Halsey Rogers, “Missing in Action: Teacher and Health Worker Absence in Developing Countries,” *Journal of Economic Perspectives*, 20 (2006), 91–116.

Duflo, E. and R. Hanna (2005) “Monitoring Works: Getting Teachers to Come to School”, NBER Working Paper No. 11880, Cambridge, Massachusetts, http://www.nber.org/papers/w11880 (Accessed on 30 December 2012).

Duthilleul, Y. (2005): "Lessons Learnt in the Use of 'Contract' Teachers," International Institute for Educational Planning, UNESCO.

Esther Duflo, Pascaline Dupas, Michael Kremer, (2009) “Additional Resources versus Organizational Changes in Education: Experimental Evidence from Kenya”, unpublished working paper.

Esther Duflo, Pascaline Dupas, Michael Kremer, (2012) “School Governance, Teacher Incentives, and Pupil-Teacher Ratios: Experimental Evidence from Kenyan Primary Schools”, NBER Working Paper No. 17939, Cambridge, Massachusetts, http://www.nber.org/papers/w17939 (Accessed on 30 December 2012).

Glewwe, Paul, Naumam Ilias and Michael Kremer (2010). “Teachers Incentives.” *American Economic Journal: Applied Economics*, 2(3): 205-27.

Glewwe, P. and M. Kremer (2006): Schools, Teachers, and Education Outcomes in Developing Countries, Eric Hanushek and Finis Welch (eds): Handbook on the Economics of Education Vol. 2, 945-1017, New York: Elsevier.

Heyneman, S.P., Loxley, W.A., (1983). "The effect of primary-school quality on academic achievement across twenty-nine high- and low-income countries". *American Journal of Sociology*, 88 (6), 1162–1194.

Jiménez, E., Sawada, Y., (1999): "Do community-managed schools work? An evaluation of El Salvador's EDUCO Program", *World Bank Economic Review* 13 (3), 415–441.

Kremer, M., K. Muralidharan, N. Chaudhury, J. Hammer and F. Rogers (2005): Teacher Absence in India: A Snapshot, Journal of the European Economic Association Vol. 3, No. 2-3, 658-667.

Keiichi Ogawa, Makiko Nakamuro, and Eri Hoshino (2009), "Cost-Effectiveness Analysis of Education Project Evaluation by Randomized Experiments: The Case of Kenya" CICE Hiroshima University, *Journal of International Cooperation in Education*, Vol.12 No.2, 29-42.

Lavy, V. (2002): Evaluating the Effect of Teachers' Group Performance Incentives on Pupil Achievement, Journal of Political Economy Vol. 110, No. 6, 1286-1317.

Lavy, V. (2004): "Performance Pay and Teachers' Effort, Productivity and Grading Ethics", NBER Working Paper No. 10622, Cambridge, Massachusetts, http://www.nber.org/papers/w10622 (Accessed on 30 December 2012).

Mikiko Nishimura and Keiichi Ogawa (2009), "A comparative Analysis of Universal Primary Education Policy in Chana, Kenya, Malawi and Uganda," CICE Hiroshima University, *Journal of International Cooperation in Education*, Vol.12 No.1, 145-158.

Muralidharan K. and V. Sundararaman (2006), "Teacher Incentives in Developing Countries: Experimental Evidence from India", Job Market Paper, Department of Economics, Harvard University, http://www.people.fas.harvard.edu/~muralidh/Karthik_Muralidharan_JMP_Teacher_Incentives_In_Developing_Countries.pdf (Accessed on 30 December 2012).

Muralidharan, K and V. Sundararaman, (2010), "Contract Teachers: Experimental Evidence from India" Working Draft paper, May 2010.

Paul J. Gertler, Harry Anthony Patrinos, Marta Rubio-Codina **(**2012). "Empowering parents to improve education: Evidence from rural Mexico" *Journal of Development Economics*, 99(2012): 68-79.

Rachel Glennerster, Michael Kremer, Isaac Mbiti and Kudzai Takavarasha (2011). " Access and Quality in the Kenyan Education System: A Review of the Progress, Challenges and Potential Solutions" In Collaboration with The Abdul Latif Poverty Action Lab at MIT (J-PAL) and Innovations for Poverty Action (IPA). http://www.povertyactionlab.org/publication/access-and-quality-kenyan-education-system (Accessed on 30 December 2012).

Reinikka, R. and Svensson, J. (2004): "The Power of Information: Evidence from a Newspaper Campaign to Reduce Capture", Policy Research Working Paper No. 3239, Washington: The World Bank.

Sawada, Yasuyuki, and Ragatz, Andrew (2005). "Decentralization of Education, Teacher Behavior, and Outcomes: The Case of El Salvador's Educo Program," in *Incentives to Improve Teaching: Lessons from Latin America*, ed. by E. Vegas. Washington DC: The World Bank.

Task Force on the re-alignment of the education sector to the constitution of Kenya (2010), "Toward a globally competitive quality education for sustainable development.".

UWEZO Kenya (2010), "Annual Learning Assessment Report."
UWEZO Kenya (2009), "Annual Learning Assessment Report."

UWEZO East Africa (2012), “Are our children learning, Literacy and Numeracy across East Africa”, Nairobi Kenya

Yuichi SASAOKA and Makiko NISHIMURA (2007), “Education Decentralization in Low Income Countries: Contradiction with Universal Primary Education (UPE) Policy, *Journal of International Development Research*, Vol.16 No.2, 21-33.

Table [1] The number and percentage of schools that answers how many months have passed since the previous Quality Assurance Officer visit

School year	Number of Months	Month	Freq.	Percent	Cum.	School term
Year 2012	1	March	13	0.31	0.31	Term 1
	2	February	974	23	23.31	
	3	January	662	15.64	38.95	
Year 2011	4	December	10	0.24	39.18	Term 3
	5	November	219	5.17	44.36	
	6	October	207	4.89	49.24	
	7	September	182	4.3	53.54	
	8	August	18	0.43	53.97	
	9	July	62	1.46	55.43	Term 2
	10	June	87	2.05	57.49	
	11	May	64	1.51	59	
	12	April	12	0.28	59.28	
	13	March	54	1.28	60.56	
	14	February	82	1.94	62.49	Term 1
	15	January	153	3.61	66.11	
Year 2010	17	November	7	0.17	66.27	Term 3
	18	October	19	0.45	66.72	
	19	September	15	0.35	67.08	
	20	August	2	0.05	67.12	Term 2
	21	July	11	0.26	67.38	
	22	June	5	0.12	67.5	
	23	May	6	0.14	67.64	
	25	March	5	0.12	67.76	
	26	February	10	0.24	68	Term 1
	27	January	30	0.71	68.71	
Year 2009			30	0.71	69.41	
Year 2008			29	0.68	70.1	
	Missing		1,266	29.9	100	
	Total		4,234	100		

Table [2] The UWEZO Kenya National Assessment Scale

Annual Assessment	Round 1	Round 2	Round 3
Survey Period	October, 2009	February – March, 2011	February – March, 2012
Districts reached (of census 158)	70	124	156
Households reached	40,386	72,106	90,820
Children assessed	68,945	134,243	153,900
Schools reached	2,030	3,574	4,543

Source: UWEZO Kenya (2009), (2010), (2012)

Table [3] Descriptive statistics for Schools, village and pupils characteristics before imposing the common support condition

Grade 4	Obs	Mean	Variance	Std.	Min	Max
Dependent Variable						
Math	3778	6.82	1.67	1.29	1	8
English	3778	4.08	0.77	0.88	1	5
Swahili	3778	4.19	0.78	0.88	1	5
Independent Variable (School level)						
PTA teacher ratio	3778	26.98	439.33	20.96	2	100
Log of pupil teacher ratio	3778	3.50	0.33	0.58	0.69	6.86
Log of classsize	3778	3.60	0.22	0.46	0.81	6.58
School fenced dummy (1 if school is fenced and 0 otherwise)	3778	0.69	0.21	0.46	0.00	1.00
Log of pupil teacher ratio (Quadratic)	3778	12.60	21.12	4.60	0.48	47.05
Log of classsize (Quadratic)	3778	13.14	12.29	3.51	0.66	43.34
Log of pupil teacher ratio (Quadratic)	3778	46.72	873.94	29.56	0.33	322.77
Log of classsize (Quadratic)	3778	48.85	444.65	21.09	0.53	285.33
Independent Variable (Household level averaged at school)						
Male household head	3778	0.76	0.13	0.36	0	1
Year dummy	3778	0.54	0.25	0.50	0	1
Age of mother	3778	35.95	41.16	6.42	18	75
Age of pupils	3778	10.64	2.03	1.43	6	16
Years of education for mother	3778	5.68	11.39	3.37	0	13
Years of education for father	3778	6.66	13.03	3.61	0	17
Asset (phone)	3778	0.63	0.16	0.40	0	1
Quality of house wall (1 if material is Polythene)	3778	0.01	0.00	0.06	0	1
Quality of house wall (1 if material is Iron sheet)	3778	0.07	0.05	0.23	0	1
Quality of house wall (1 if material is Timber)	3778	0.10	0.07	0.27	0	1
Quality of house wall (1 if material is Stone/bricks)	3778	0.17	0.12	0.34	0	1
Number of meals that pupils take in a day	3778	2.72	0.22	0.47	1	3
Payment to school extra tuition	3778	0.41	0.20	0.45	0	1
Number of household members	3778	6.84	3.95	1.99	1	24
Independent Variable (Village level)						
Electricity dummy (1 if there is an electricity infrastructure in the village and 0 otherwise)	3778	0.43	0.24	0.49	0	1
Tarmac road dummy (1 if there is a tarmac road and 0 otherwise)	3778	0.13	0.11	0.34	0	1

Table [3.1] Schools before Common support condition imposed and after.

Grade 4

Common support before

	Observation	mediun	mean	Min	Max
1st quantile	947	10	9.45301	3	13
2nd quantile	1088	19	18.47059	14	22
3rd quantile	978	28	28.1411	23	33
4th quantile	765	50	59.29804	35	100
	3778				

Common support after

	Observation	mediun	mean	Min	Max
1st quantile	947	10	9.45301	3	13
2nd quantile	1083	19	18.47461	14	22
3rd quantile	964	28	28.09647	23	33
4th quantile	571	44	47.71629	35	100
	3565				

Grade 3

Common support before

	Observatior	mediun	mean	Min	Max
1st quantile	944	10	9.443856	2	13
2nd quantile	1051	19	18.50048	14	22
3rd quantile	961	27	27.99688	23	33
4th quantile	772	50	59.28627	35	100
	3728				

Common support after

	Observatior	mediun	mean	Min	Max
1st quantile	942	10	9.440552	3	13
2nd quantile	1050	19.5	18.50286	14	22
3rd quantile	949	27	27.9568	23	33
4th quantile	579	44	47.51813	35	100
	3520				

Grade 2

Common support before

	Observation	mediun	mean	Min	Max
1st quantile	1004	10	9.959163	3	14
2nd quantile	959	20	18.96038	15	22
3rd quantile	970	27	28.02268	23	33
4th quantile	773	50	60.35058	35	100
	3706				

Common support after

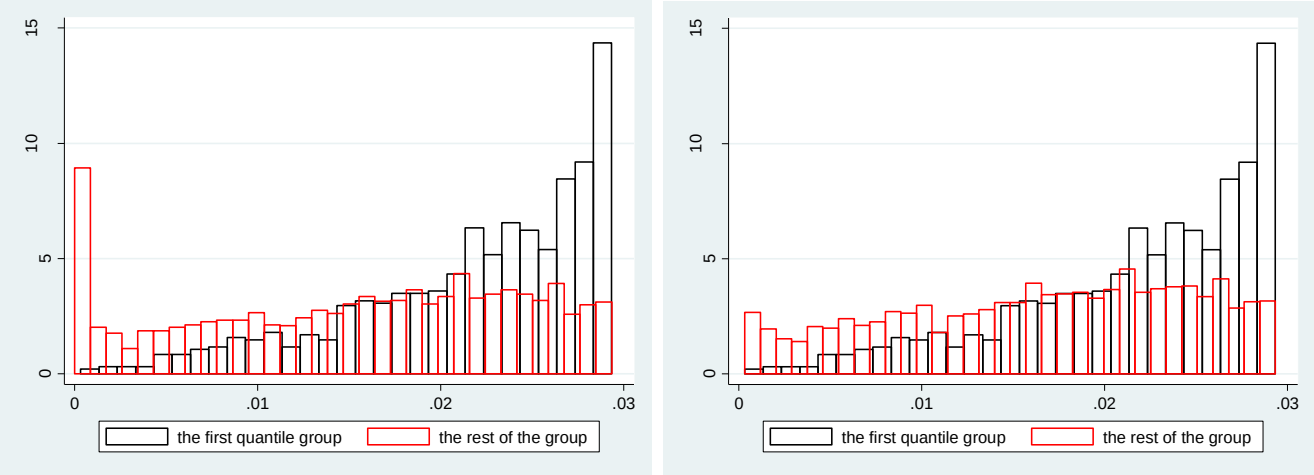
	Observation	mediun	mean	Min	Max
1st quantile	1002	10	9.956088	3	14
2nd quantile	957	20	18.96029	15	22
3rd quantile	958	27	27.97495	23	33
4th quantile	567	44	48.37919	35	100
	3484				

Table [3.2] Descriptive statistics for restricted schools satisfied with common support condition

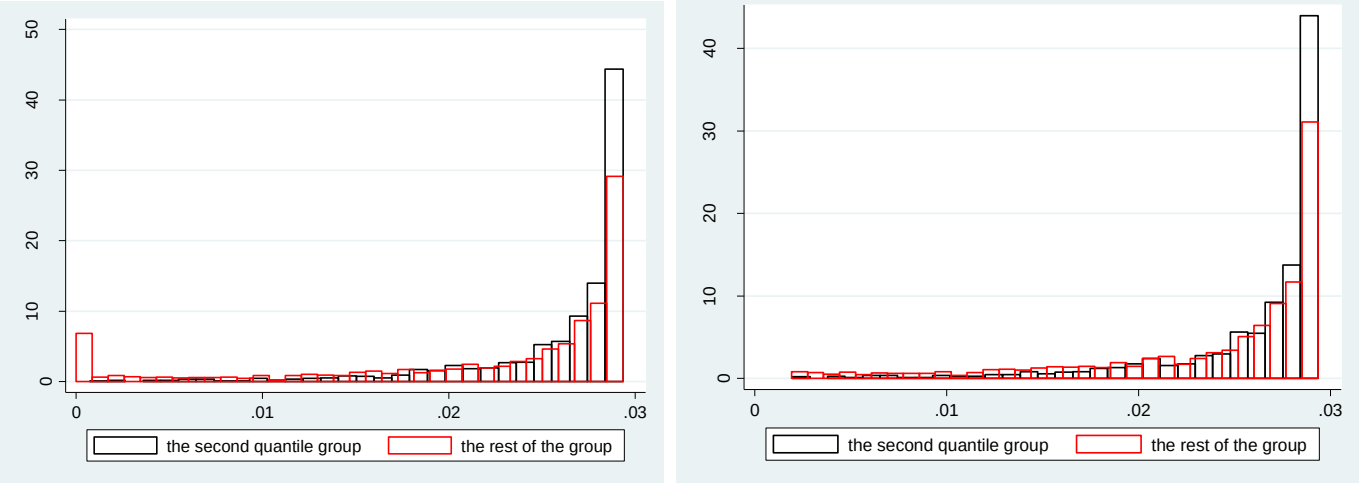
Grade 4	Obs	Mean	Variance	Std.	Min	Max
Dependent Variable						
Math	3565	6.82	1.68	1.29	1	8
English	3565	4.08	0.77	0.88	1	5
Swahili	3565	4.19	0.77	0.88	1	5
Independent Variable (School level)						
PTA teacher ratio	3565	23.36	198.12	14.08	2	100
Log of pupil teacher ratio	3565	3.41	0.17	0.41	0.69	4.69
Log of classsize	3565	3.59	0.21	0.46	0.81	6.58
School fenced dummy (1 if school is fenced and 0 otherwise)	3565	0.69	0.21	0.46	0.00	1.00
Log of pupil teacher ratio (Quadratic)	3565	11.82	7.59	2.76	0.48	21.99
Log of classsize (Quadratic)	3565	13.08	12.08	3.48	0.66	43.34
Log of pupil teacher ratio (Quadratic)	3565	41.46	202.60	14.23	0.33	103.13
Log of classsize (Quadratic)	3565	48.51	429.55	20.73	0.53	285.33
Independent Variable (Household level averaged at school)						
Male household head	3565	0.76	0.13	0.36	0	1
Year dummy	3565	0.56	0.25	0.50	0	1
Age of mother	3565	35.96	41.34	6.43	18	75
Age of pupils	3565	10.63	2.02	1.42	6	16
Years of education for mother	3565	5.71	11.34	3.37	0	13
Years of education for father	3565	6.70	12.94	3.60	0	17
Asset (phone)	3565	0.63	0.16	0.40	0	1
Quality of house wall (1 if material is Polythene)	3565	0.01	0.00	0.06	0	1
Quality of house wall (1 if material is Iron sheet)	3565	0.07	0.05	0.23	0	1
Quality of house wall (1 if material is Timber)	3565	0.10	0.08	0.27	0	1
Quality of house wall (1 if material is Stone/bricks)	3565	0.18	0.12	0.35	0	1
Number of meals that pupils take in a day	3565	2.72	0.22	0.47	1	3
Payment to school extra tuition	3565	0.41	0.20	0.45	0	1
Number of household members	3565	6.84	3.97	1.99	1	24
Independent Variable (Village level)						
Electricity dummy (1 if there is an electricity infrastructure in the village and 0 otherwise)	3565	0.43	0.25	0.50	0	1
Tarmac road dummy (1 if there is a tarmac road and 0 otherwise)	3565	0.13	0.12	0.34	0	1

Figure 1 Histogram of generalized propensity score of grade 4 sample before imposing the common support condition and after

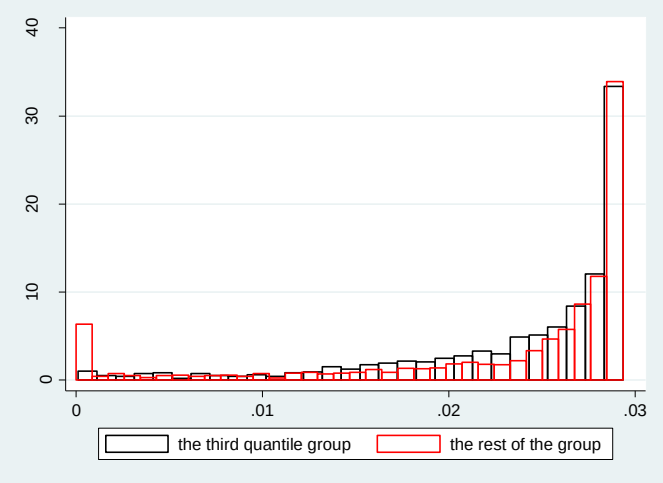
[1st quantile group]

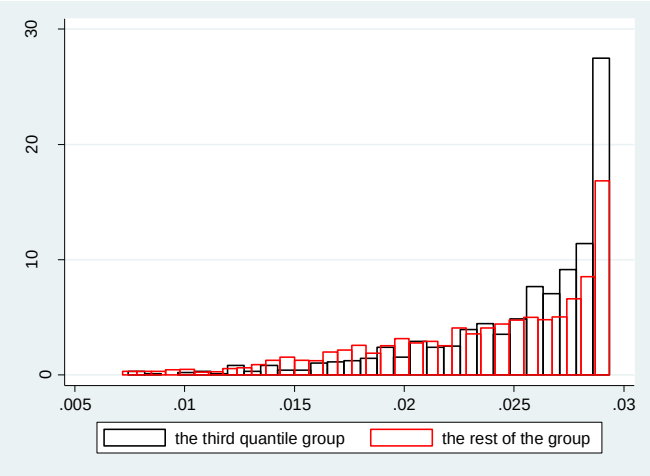


[2nd quantile group]

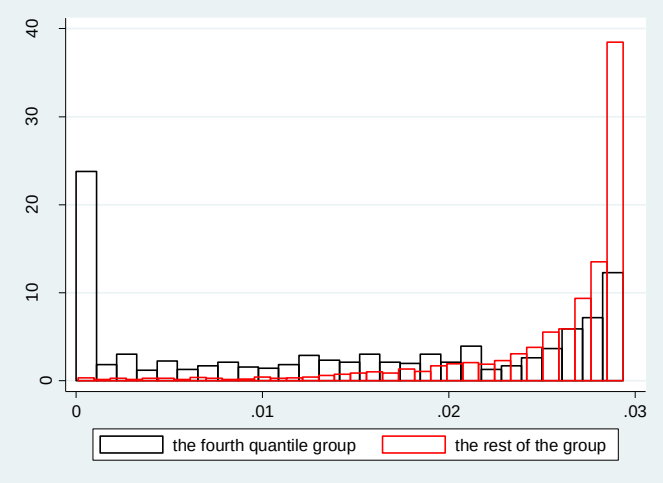


[3rd quantile group]





[4th quantile group]



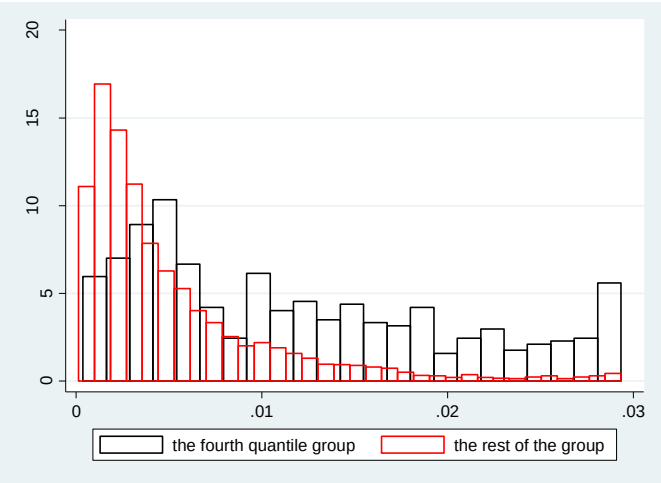


Table [4.1] Generalized propensity score estimation result (157 district dummy is included)

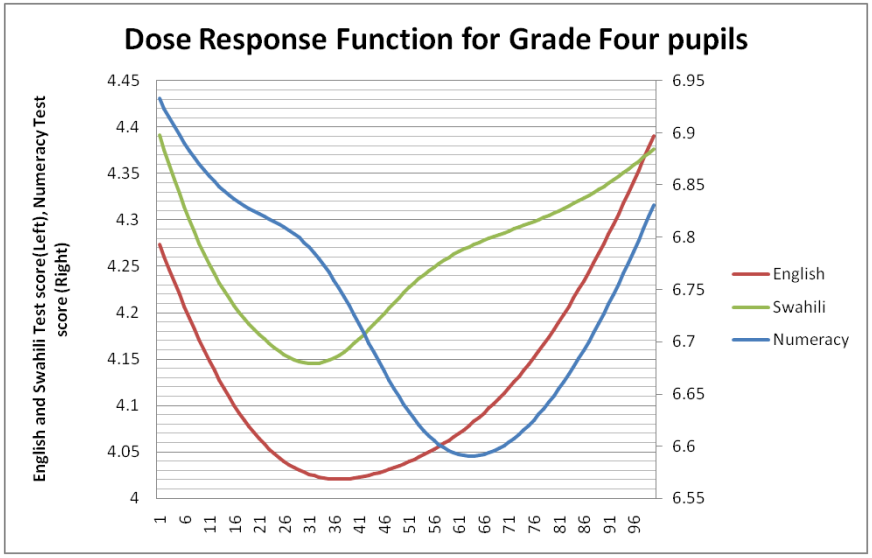
Dependent Variable: PTA teacher ratio	Grade four	Grade three	Grade two
Male household head	-0.0251	0.0136	-0.00109
	(0.0230)	(0.0229)	(0.0224)
Year dummy	-0.0262	-0.00728	-0.0225
	(0.0197)	(0.0198)	(0.0200)
Age of mother	-0.00173	-0.000902	-0.00143
	(0.00127)	(0.00129)	(0.00127)
Age of pupils	0.00476	0.00494	0.0162***
	(0.00558)	(0.00555)	(0.00575)
Years of education for mother	-0.00118	-0.00166	-0.00404
	(0.00372)	(0.00388)	(0.00386)
Years of education for father	-0.00797**	-0.00666*	0.00227
	(0.00320)	(0.00353)	(0.00350)
Asset (phone)	-0.0438**	-0.0427**	-0.108***
	(0.0209)	(0.0212)	(0.0211)
Quality of house wall (1 if material is Polythene)	0.279**	0.0126	-0.143
	(0.115)	(0.114)	(0.0906)
Quality of house wall (1 if material is Iron sheet)	0.0386	0.0216	-0.0894**
	(0.0363)	(0.0383)	(0.0391)
Quality of house wall (1 if material is Timber)	0.0938**	-0.00133	-0.0160
	(0.0428)	(0.0465)	(0.0429)
Quality of house wall (1 if material is Stone/bricks)	-0.0432	-0.163***	-0.0768**
	(0.0358)	(0.0378)	(0.0386)
Number of meals that pupils take in a day	-0.00321	0.0166	0.0132
	(0.0183)	(0.0180)	(0.0181)
Payment to school extra tuition	0.0409**	0.0105	0.0186
	(0.0194)	(0.0206)	(0.0211)
Number of household members	-0.00423	-0.00202	0.00156
	(0.00427)	(0.00413)	(0.00378)
Log of pupil teacher ratio	-2.669***	-3.034***	-3.361***
	(0.409)	(0.372)	(0.366)
Log of classsize	0.712	1.541***	0.975
	(0.730)	(0.447)	(0.653)
School fenced dummy (1 if school is fenced and 0 otherwise)	-0.115***	-0.0962***	-0.118***
	(0.0177)	(0.0178)	(0.0183)
Electricity dummy (1 if there is an electricity infrastructure in the village and 0	-0.0980***	-0.109***	-0.117***
	(0.0177)	(0.0178)	(0.0180)
Tarmac road dummy (1 if there is a tarmac road and 0 otherwise)	-0.0369	-0.0367	-0.0136
	(0.0261)	(0.0251)	(0.0267)
Log of pupil teacher ratio (Quadratic)	0.829***	0.917***	0.991***
	(0.0922)	(0.0836)	(0.0842)
Log of classsize (Quadratic)	-0.378**	-0.621***	-0.411***
	(0.175)	(0.110)	(0.157)
Log of pupil teacher ratio (Cubit)	-0.0661***	-0.0728***	-0.0784***
	(0.00683)	(0.00618)	(0.00636)
Log of classsize (Cubic)	0.0401***	0.0638***	0.0407***
	(0.0135)	(0.00899)	(0.0123)
Constant	6.000***	5.404***	6.217***
	(0.890)	(0.459)	(0.780)
Observations	3,778	3,728	3,706

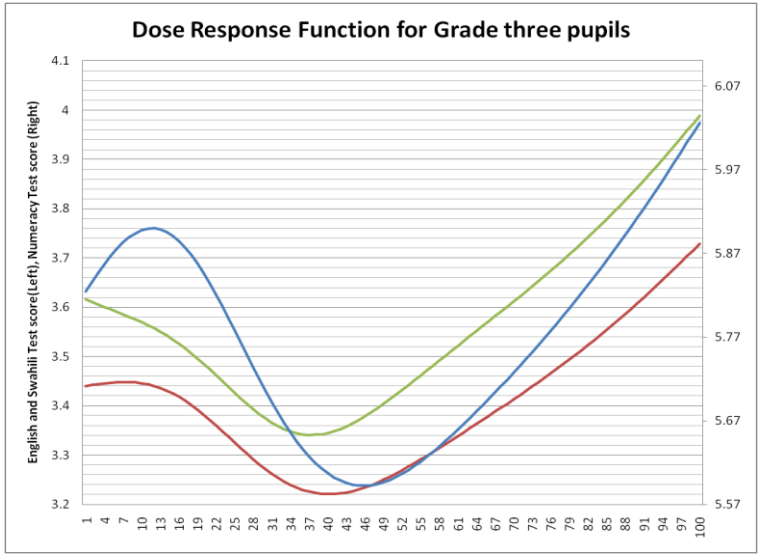
Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table [4.2] The Balancing Property of covariates for estimation sample

	Adjusted	Not Adjusted	Adjusted	Not Adjusted	Adjusted	Not Adjusted
	0 <PTA ratio <=16		16 <PTA ratio<=26		26 <PTA ratio	
Male household head	-0.01266	-0.0239	-0.0024	-0.01	0.0263	0.0347
	[-0.358]	[-1.91]*	[-0.144]	[-0.77]	[0.728]	[2.71]***
Year dummy	0.07	0.0046	0.02786	0.0195	-0.1	-0.0238
	[1.704]	[0.26]	[0.706]	[1.09]	[-2.324]	[-1.34]
Age of mother	0.024	-0.0846	-0.3334	-0.3145	0.2533	0.3951
	[0.038]	[-0.38]	[-0.612]	[-1.35]	[0.552]	[1.72]*
Age of pupils	0.0903	0.225	0.04896	0.0868	-0.207	-0.3195
	[0.692]	[4.54]***	[0.486]	[1.69]*	[-1.598]	[-6.33]***
Years of education for mother	-0.1876	-0.753	-0.1615	-0.356	0.5595	1.1335
	[-0.616]	[-6.44]***	[-0.716]	[-2.93]***	[1.926]*	[9.56]***
Years of education for father	-0.24426	-0.8031	-0.2212	-0.404	0.5926	1.2326
	[-0.648]	[-6.43]***	[-0.852]	[-3.11]***	[1.972]*	[9.73]***
Asset (phone)	-0.0279	-0.0925	0.01088	-0.0046	0.0367	0.101
	[-0.866]	[-6.72]***	[0.29]	[-0.32]	[1.064]	[7.20]***
Quality of house wall (1 if material is Polythene)	-0.0038	0.0009	0.00168	0.0021	0.0007	-0.003
	[-0.376]	[0.43]	[0.434]	[0.97]	[0.218]	[-1.39]
Quality of house wall (1 if material is Iron sheet)	-0.00568	-0.0082	0.00642	0.0073	-0.003	0.0014
	[-0.258]	[-1.01]	[0.344]	[0.88]	[-0.138]	[0.17]
Quality of house wall (1 if material is Timber)	-0.00536	-0.0313	-0.0169	-0.0164	0.0398	0.0486
	[-0.284]	[-3.27]***	[-0.78]	[-1.66]*	[1.318]	[4.99]***
Quality of house wall (1 if material is Stone/bricks)	-0.03102	-0.0742	0.0135	0.0012	0.0323	0.0763
	[-1.116]	[-6.18]***	[0.534]	[0.10]	[1.066]	[6.22]***
Number of meals that pupils take in a day	-0.01958	-0.0544	-0.0089	-0.022	0.0484	0.0782
	[-0.49]	[-3.33]***	[-0.314]	[-1.30]	[1.206]	[4.70]***
Payment to school extra tuition	0.02142	-0.0002	-0.0108	-0.0189	-0.012	0.0187
	[0.61]	[-0.01]	[-0.342]	[-1.16]	[-0.292]	[1.16]
Number of household members	0.1096	0.2274	-0.0258	-0.0223	-0.155	-0.2156
	[0.744]	[3.27]***	[-0.156]	[-0.31]	[-0.814]	[-3.04]***
Log of pupil teacher ratio	-0.03436	0.039	-0.0333	-0.021	0.0502	-0.0202
	[-0.972]	[2.72]***	[-0.808]	[-1.41]	[1.426]	[-1.38]
Log of classsize	0.0482	0.0481	-0.0121	-0.0119	-0.07	-0.0386
	[1.304]	[2.98]***	[-0.22]	[-0.71]	[-1.372]	[-2.34]**
School fenced dummy (1 if school is fenced and 0 otherwise)	0.03348	-0.0311	-0.0098	-0.0247	-0.002	0.0566
	[0.81]	[-1.93]*	[-0.27]	[-1.49]	[-0.056]	[3.45]***
Electricity dummy (1 if there is an electricity infrastructure in the village and 0	-0.06998	-0.1966	0.03278	0.0078	0.063	0.1977
	[-1.854]	[-11.58]***	[0.818]	[0.44]	[1.652]*	[11.38]***
Tarmac road dummy (1 if there is a tarmac road and 0 otherwise)	-0.02464	-0.0677	0.0046	0.0002	0.0365	0.0705
	[-0.914]	[-5.71]***	[0.156]	[0.02]	[1.148]	[5.82]***
Log of pupil teacher ratio (Quadratic)	-0.28448	0.2423	-0.2324	-0.13	0.3756	-0.1263
	[-1.21]	[2.52]**	[-0.816]	[-1.31]	[1.614]	[-1.28]
Log of classsize (Quadratic)	0.34274	0.3331	-0.0809	-0.0655	-0.532	-0.2839
	[1.21]	[2.75]***	[-0.178]	[-0.52]	[-1.316]	[-2.29]**
Log of pupil teacher ratio (Cubit)	-1.72664	1.1265	-1.2063	-0.597	2.0978	-0.594
	[-1.428]	[2.27]**	[-0.786]	[-1.16]	[1.756]*	[-1.17]
Log of classsize (Cubic)	1.89122	1.7456	-0.361	-0.2191	-3.16	-1.609
	[1.104]	[2.42]**	[-0.112]	[-0.29]	[-1.246]	[-2.18]**

Figure 2, 3, 4 the estimated dose response function for grade four, three and two pupils





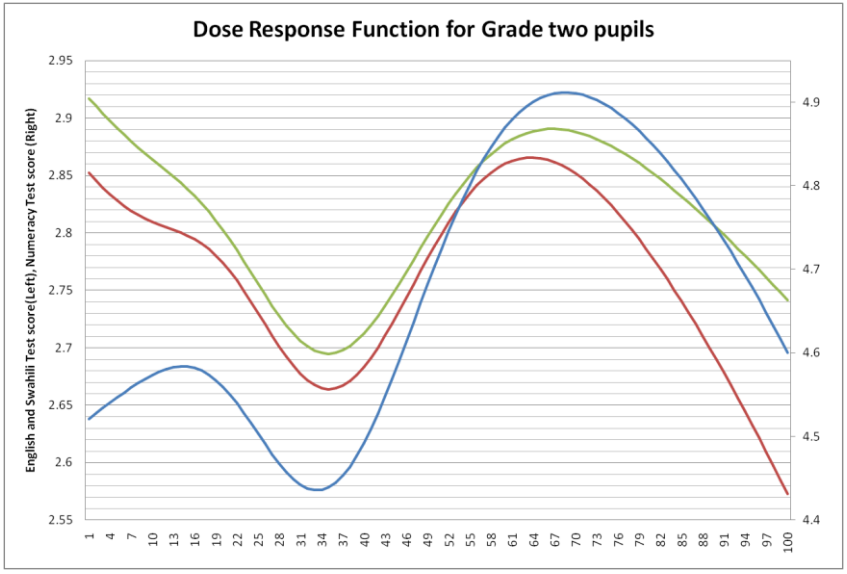


Figure 5 Central Province, Grade 4 pupil school average

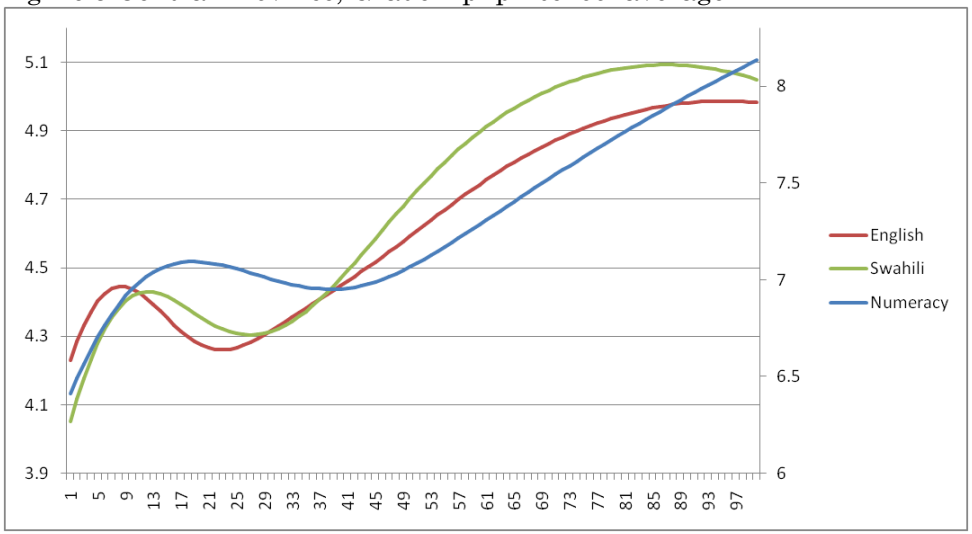


Figure 6 Coast Province, Grade 4 pupil school average

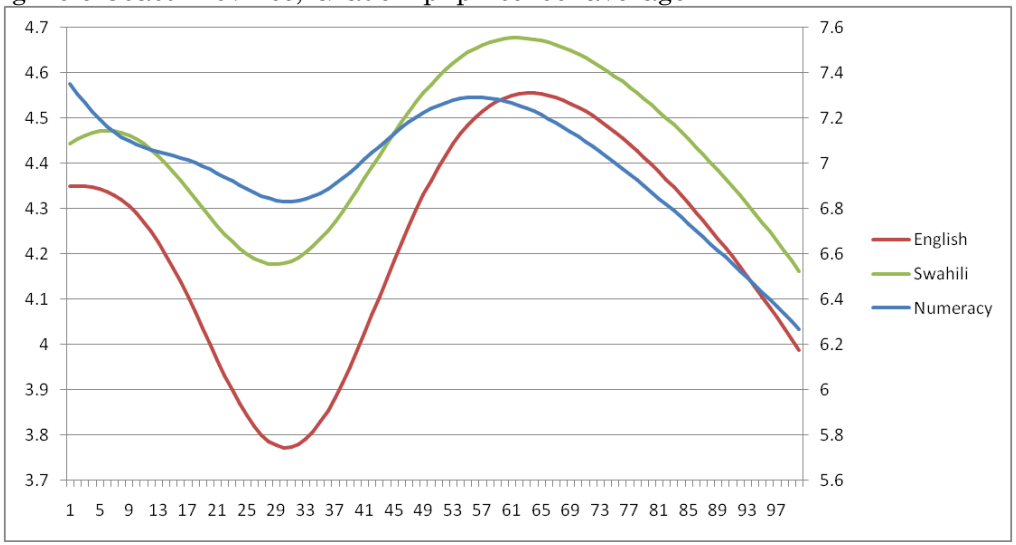


Figure 7 North Eastern Province, Grade 4 pupil school average

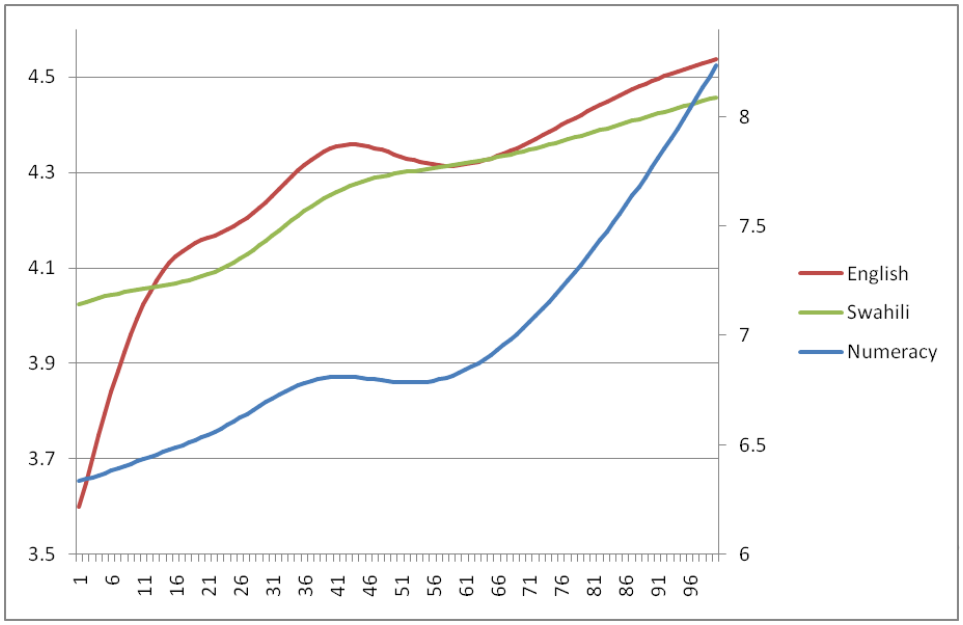


Figure 8 Eastern Province, Grade 4 pupil school average

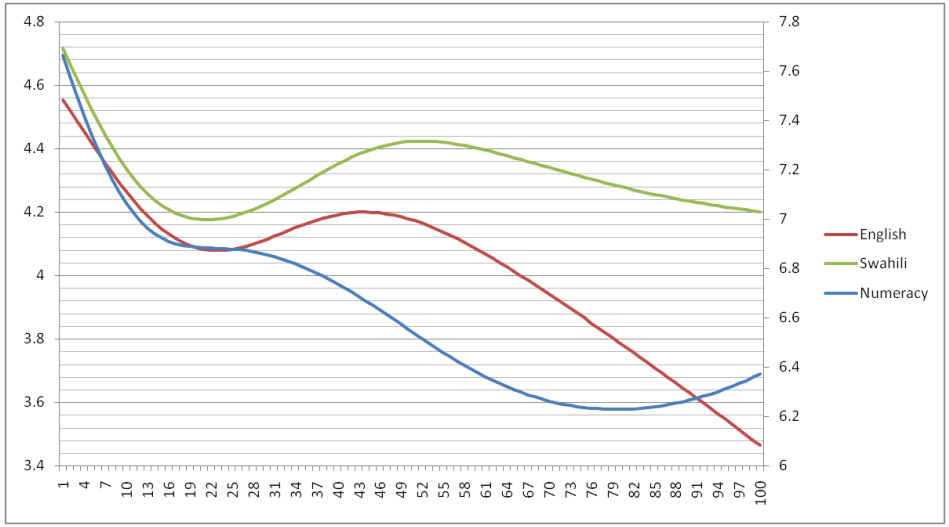


Figure 9 Western Province, Grade 4 pupil school average

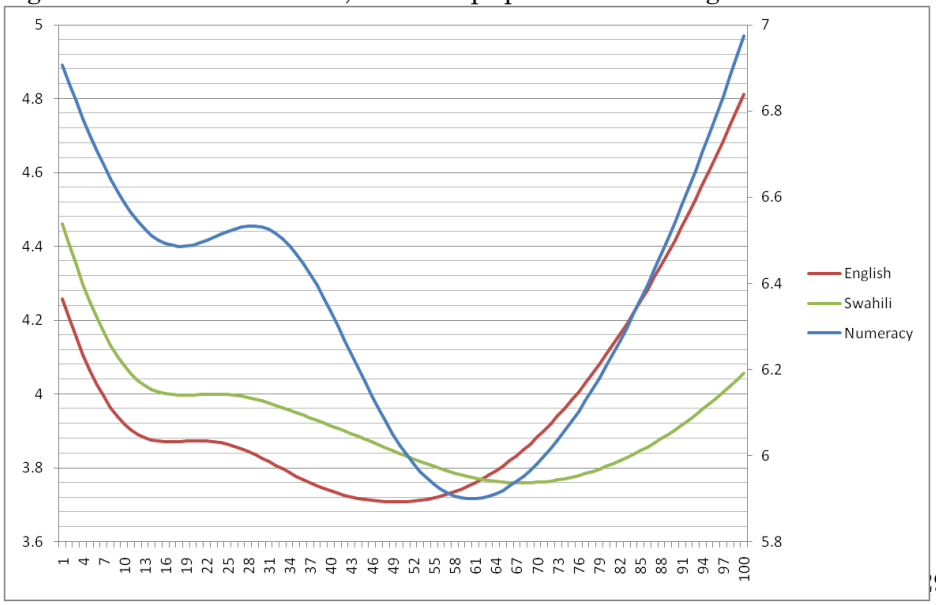


Figure 10 Rift Valley Province, Grade 4 pupil school average

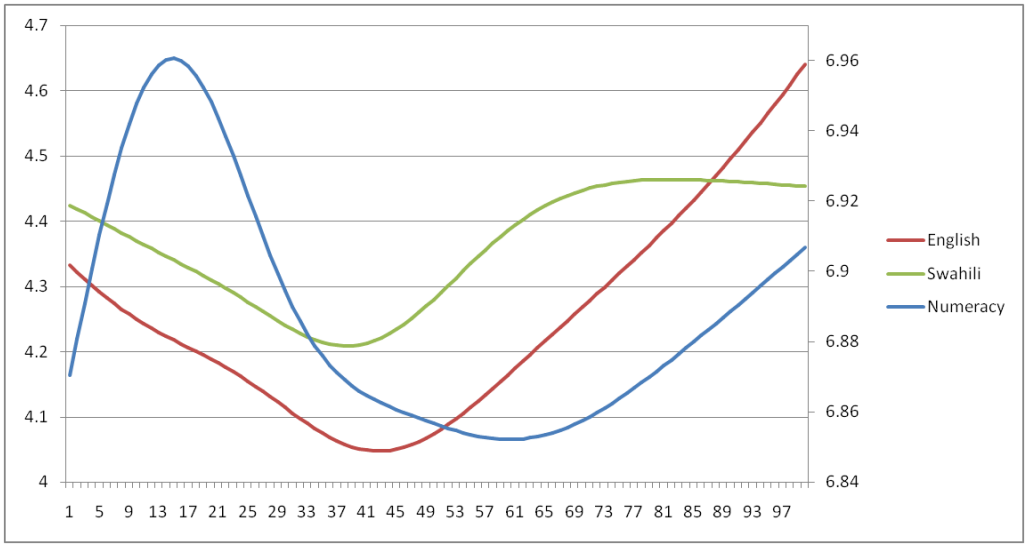


Figure 11 Nyanza Province, Grade 4 pupil school average