The relative effectiveness and costs of contract and regular teachers in India

by

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Abstract

While use of contract teachers provides a low-cost way to increase teacher numbers, it raises the quality concern that these less trained teachers may be less effective. We estimate the causal contract-teacher effect on student achievement using school and pupil fixed effects, value-added, and saturated models of the education production function, using Indian data. We also present School Fixed Effects teacher pay equations and predict achievement marks per Rupee from regular and contract teachers. We find that despite being paid just a third of the salary of regular teachers with similar observed characteristics, contract teachers produce higher student learning.

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1. Introduction

A central plank of India's primary school reforms in the past 15 years has been the provision of low-cost contract teachers, in official data called 'para' teachers. Use of contract teachers increased rapidly in India since the mid-1990s and there were 543,671 contract teachers in India in 2008-09[1].

The officially stated rationale for provision of contract teachers is to achieve three major equity and efficiency aims in an affordable way: expanding access to schooling in unserved communities; eliminating single-teacher schools and relieving multi-grade teaching; and reducing high pupil teacher ratios. Regular teacher pay scales are high. For instance, in Uttar Pradesh, the ratio of regular teacher pay to state per capita GDP was 7:1 in 2005 and since then regular teacher salaries have nearly doubled, following implementation of the Sixth Pay Commission's recommendations (Kingdon, 2010). Nationally, contract teachers' salary rate in 2005 was on average about 35% of regular teachers' pay rate, and this is likely to have fallen below 25% following Sixth Pay Commission related increases in regular teacher salaries (Kingdon and Sipahimalani-Rao, 2010). Contract teacher schemes are favoured because they expand schooling access, increase teacher numbers, relieve multi-grade teaching and reduce class sizes in a fiscally manageable way.

Although the schemes vary across states, generally contract teachers have renewable (often annually renewable) contracts rather than regular teachers' lifetime employment guarantees. They are usually not required to have pre-service teacher training and the educational qualification requirements for contract teachers are mostly lower than those for regular teachers. Finally, contract teachers are typically recruited and paid by the village local government, rather than being employed directly by the state government as regular teachers are.

Given that teachers are the most important input into primary schools, the relative effectiveness of contract and regular teachers – and thus whether the government should fund contract teacher schemes or scrap them – is one of the most policy relevant and quality-focused issues in Indian basic education today. On the one hand, their use provides a low-cost way for the state to increase the number of teachers in the face of rising student populations, budgetary troubles and rapid real increases in salaries of regular teachers. On the other, it raises educational quality and educational equity concerns[2]. The quality

[1] Authors' calculations using the percentage of para-teachers in all schools (9.39%) and the total number of elementary school teachers (5,789,898) based on DISE (2009).
[2] Govinda and Josephine (2004), Kumar, *et al* (2001)

concern is the fear that these less trained and lower paid teachers may be less effective in imparting learning. The (related) equity concern arises because contract teachers are often appointed in the remoter schools or in the 'Education Guarantee' schools that serve poorer children (e.g. child labourers, small-habitations or tribal children), raising the fear that poorer children are potentially being condemned to lower quality teachers, exacerbating social inequality[3].

The relative effectiveness of regular and contract teachers is not obvious, since international research fails to show a consistent positive association between certification (teacher education, training), tenure and salary on the one hand and student achievement on the other. Moreover, even if lower education, training and salary reduce contract teachers' effectiveness, there may be compensating positive effects: being appointed by village local government, contract teachers are likely to be more locally accountable than regular teachers. Further, contract teachers may have greater incentive to apply effort to ensure contract renewal, unlike regular teachers whose tenures are secure, especially given a high graduate unemployment rate of 11%[4] and paucity of well-remunerated employment. In sum, it cannot be presumed that contract teachers are necessarily less effective in imparting learning than regular teachers. Moreover, the employment of contract teachers is expected to lead to a reduction of pupil teacher ratios and to relieve multi-grade teaching, and this may be conducive to greater learning. Their relative effectiveness is thus an empirical issue worthy of examination.

Since the early 2000s, the effectiveness of contract and regular teachers in India has attracted research interest (Pratichi Trust, 2002; Leclercq, 2002; Govinda and Josephine, 2004; EdCil, 2007, NCAER, 2008). Using descriptive statistics these studies find that achievement and/or attendance levels of children taught by contract and regular teachers were similar. Sankar (2008a) fits child achievement regressions for three Indian states (Andhra, Madhya Pradesh and Uttar Pradesh) and after controlling for children's home background, finds no significant difference between the learning levels of students taught by contract and regular teachers. However, if contract teachers are differ from regular teachers in their unobserved characteristics (e.g. if different types of individuals tend to become contract teachers than those who become regular teachers), the contract teacher dummy variable will be endogenous, yielding biased estimates of the contract teacher 'effect'. Goyal and Pandey (2009) and Kingdon and Sipahimalani Rao (2010) find that contract teachers have significantly higher effort (attendance rate and time on teaching task) than regular teachers *within the same school*. Finally, Muralidharan and Sundararaman (2009) use experimental data from Andhra Pradesh to find that the provision of a contract teacher in randomly selected 100 treatment schools led to child test scores that were higher by 0.15 SD in maths and 0.09 SD in language, compared to those in control schools. However, in this paper, the contract teacher

[3] Drèze and Sen (2002), Leclercq (2002)
[4] Based on our analysis of Indian National Sample Survey (2004-05).

effect is indistinguishable from the effect of the reduction in class size that accompanies the provision of an extra contract teacher[5]. A true randomized trial of the contract teacher effect requires one of the following: (a) an additional treatment group who were allocated an extra regular teacher (to act as the comparator for the group that were allocated an extra contract teacher), (b) the replacement of a regular teacher with a contract teacher (which would leave class-sizes unchanged), or (c) the random allocation of pupils to contract and regular teachers within a grade after the hiring of additional teachers. In the spirit of (c), Duflo, Dupas and Kremer (2009) exploit random allocation of teachers across grade 1 classes following the hiring of contract teachers in Kenya, to isolate a contract teacher effect. They find that pupils assigned to contract teachers score significantly higher than those assigned to regular teachers.

The current paper attempts to shed further light on the contract teacher effect in India using a unique rich dataset collected by Kingdon, Banerji and Chaudhari (2008). We tested the learning achievement level of individual children in two grades (grades 2 and 4), in two subjects (maths and language) and at two points in time (start and end of the school year). We also have matched data on the characteristics of the teacher that taught a given grade a given subject most through the year (by head-teacher's report). This data permits estimation of the contract teacher effect at the student level using school and pupil fixed effects models and value added models, and it allows us to control for changes in class-size, multi-grade teaching and pedagogical style, which allow us to get close to the causal contract teacher effect. In addition, the use of a saturated model of the achievement production function, also allows us to look at how the contract teacher effect works.

Section 2 sets out the methodology and data used. Section 3 presents the results and the last section concludes.

2. Data and methodology

Data

The data used in this paper come from the SchoolTells survey of primary schools in two north Indian states: Uttar Pradesh and Bihar. These are two of the most educationally challenged states of India. The SchoolTells survey was carried out in the 2007-08 school year in 160 rural primary schools across 10 districts of the sample states. It yielded achievement data on over 4000 students of grades 2 and 4 and on their teachers and schools. Each school was visited four times in the school year. Students were tested in language and maths at the start and end of the school year, approximately nine months apart. Although the survey included 35 private schools, we have used only government schools in the analysis in this paper as contract teachers are used only in government-funded schools. The survey provides an unusually

[5] In addition the authors find that the size of the contract teacher effect is greater in the lower than in higher grades, where they also find the reduction in class-size to be greatest.

rich source of data with detailed questions on the children's personal traits (age, gender, height, illness); family background (parental education, household asset ownership); teacher characteristics (qualifications, training, gender, age, regular/contract status, absence rate and time on task); and a wide range of school quality factors. Given high teacher absence rates in north Indian schools (Kremer, et al, 2005), children in a given grade are often taught by a teacher other than the one assigned to teach them. In matching students to teachers, we rely on the head-teacher's report of which teacher teaches a given subject to class 2 and class 4 the most during the year.

The same achievement test was used for students of grades 2 and 4. It tested competencies that span the kind of material children encounter in the textbooks of grades 2 through 4. It was understood that most children in grade 2 may not be able to do the more difficult questions. The same type of achievement test with the same competencies tested was used in time period 2 (near the end of the school year) as in time period 1 (at the start of the school year).

To render achievement level comparable across subjects, grades and time periods, we converted absolute achievement scores into z-scores. The distribution of absolute marks in maths and language (grades 2 and 4 and both time-periods taken together) is shown in Figure 1. Appendix Table 1 sets out the descriptive statistics of the variables used in the analysis.

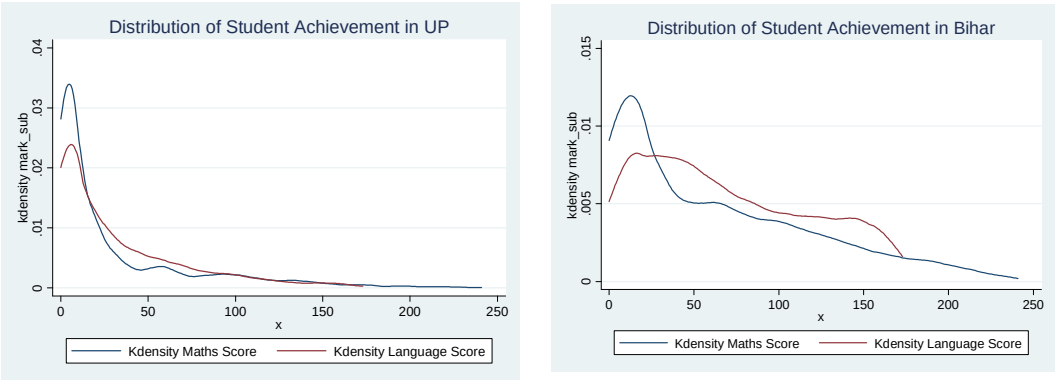

Figure 1: Distribution of student achievement

Figure 1 is striking due to the severe left hand skewness of the distribution or marks, especially in UP. Given that the figures show marks for both grades 2 and 4, one would expect a bi-modal distribution, instead, the majority of marks are distributed towards the left of the graph, with a very long tale. The situation is starker for mathematics than for language achievement. The exception to this is language scores in Bihar, which are somewhat more normally distributed. The figure suggests that learning levels are very low and do not improve much between grades, a cause of real concern. Such low levels of achievement are not confined to our sample, with the Annual Status of Education (ASER 2009) finding that only 37.6% of grade 4 children in India can read a grade two level text.

Differences between regular and contract teachers' characteristics

Before examining the main question, we present some descriptive statistics (Table 1) to highlight key differences between teacher types. In both states contract teachers are noticeably younger than regular teachers, and this is also partly reflected in their tenures. In Bihar a far higher proportion of contract than regular teachers are female but in UP the proportions are similar. Salary differences are stark: contract teachers earn only a quarter as much as regular teachers in UP and a third as much in Bihar, reflecting extreme pay inequality. Despite commonly held notions, regular teachers do not have higher educational qualifications than contract teachers; indeed the opposite is true in UP. In Bihar a higher proportion of contract than regular teachers passed higher secondary exams with first-division marks. However, while the majority of regular teachers have received teacher training (95% in UP, 84% in Bihar), far fewer contract teachers have done so.

On teacher effort, contract teachers have roughly half the absence rates of regular teachers in UP but in Bihar contract teachers' absence rates are weakly higher than those of regular teachers (many of the contract teachers appointed in 2006 or later in Bihar were not local to the school, and Bihar contract teachers do not face annually renewable jobs). In both states, contract teachers spend a significantly higher proportion of their time teaching (84% compared to 75%), and are more likely to support weak children with their studies (15 [32] % of contract teachers report doing so in UP [Bihar] compared to 8 [15] % of regular teachers).

Methodology

An ideal method for impact evaluation of contract teachers would be a randomized trial with children randomly assigned to contract and regular teachers within a school. However, in general education authorities are not amenable to such an approach, and furthermore while this would give us an estimate of the effect of contract teachers, it sheds no light on why this effect exists. While propensity score matching methods may be used to create artificial comparator units, such an approach controls only for the observed differences between children taught by contract and regular teachers. In the absence of an ideal methodology, we use a number of other econometric techniques in the context of an achievement production function.

We begin with the conventional OLS baseline where we specify an achievement production function of the form:

$$(1)\ A_{ijkl} = \alpha + \beta FC_i + \delta SC_j + \lambda TC_k + \varepsilon_{ijkl}$$

Where the achievement level (A_{ijkl}) of the i^{th} student in l^{th} subject in the j^{th} school with the k^{th} teacher is determined by the vector of his/her personal and family background characteristics (FC), school characteristics (SC) and teacher characteristics (TC). The vector of teacher characteristics contains our

variable of interest, the contractual state of the teacher, in addition to his/her age, qualifications and gender.

An important problem for identifying a causal contract teacher effect is that assignment of teachers to schools may not be random, as contract teachers are often posted to more remote schools. As we have variation of teachers within schools (each child is observed in two separate subjects, and within each school there are two grades), we can use School Fixed Effects estimation to control for the non-random matching of children and teachers to particular schools that may be more or less likely to have contract teachers. Here, identification of the contract teacher effect comes only from within-school differences in teacher type, i.e. the approach controls for all observed and unobserved school factors that affect student achievement and thus reduces endogeneity bias. We specify an equation of the form:

$$(2)\ A_{ijkl} = \alpha + \beta FC_i + \lambda TC_k + (\mu_j + \varepsilon_{ikl})$$

Where μ_j captures all the observed and unobserved school-level characteristics which do not vary within schools. Furthermore, as each child was tested twice in our sample (at the start and end of the school year), we can estimate a School Fixed Effects value-added model of the achievement production function. This regresses 'change in achievement' over the school year on teacher type (teacher-type assignment for a given subject does not change over the school year), as follows:

$$(3)\ A_{ijkl,\,t+1} = \alpha + \gamma A_{ijkl,\,t} + \beta FC_i + \lambda TC_k + (\mu_j + \varepsilon_{ikl})$$

Where $A_{ijkl,\,t+1}$ denotes achievement level of the i^{th} student in the j^{th} school with the k^{th} teacher at time t+1, that is the end of the school year, with $A_{ijkl,\,t}$ as an additional control. Alternatively, we can specify achievement as a true value-added model, giving an equation of the form:

$$(4)\ [\,A_{ijkl,\,t+1} - A_{ijkl,t}\,] = \alpha + \beta FC_i + \lambda TC_k + (\mu_j + \varepsilon_{ikl})$$

This regresses change in achievement on school, teacher and family characteristics.

Finally we move to our most stringent method, pupil-level fixed effects, where the identification comes entirely from differences across subjects *within a pupil*. Suppose regular teachers are generally more able in maths and contract teachers are more able in language. Then if a child does well in language when taught by a contract teacher and does well in maths when taught by a regular teacher, one reason could be that contract teachers are systematically abler in language skills and regular teachers abler in maths area. However, any such correlation between teachers' subject-specific ability and teacher type (regular vs contract) would cause omitted variable bias in a pupil fixed effects achievement equation only if pupils can engineer to be taught a given subject by the abler teacher-type in that subject. In our sample of rural government primary schools, there are no schools with more than one class of a given grade; indeed sometimes more than one grade even sit together in a class. Classes do not split by subject – the whole class is taught all subjects. Thus, pupils are not systematically matched to particular teacher-types

for the different subjects within their grade in the school. This means that we can give the teacher type variable a causal interpretation. This gives us an equation of the form:

(5) $A_{ijkl,\,t+1} = \alpha + \gamma A_{ijkl,\,t} + \lambda TC_k + (\mu_j + \eta_i + \varepsilon_{kl})$

Where η_i captures all observed and unobserved pupil characteristics which do not vary across subjects. The composite error term represents the unobserved characteristics of the school, pupil and teachers. As we have two subjects (reading and maths) we identify the contract teacher effect thus:

(6) $[A_{ijk(Reading),\,t+1} - A_{ijk(Maths),\,t+1}] = \gamma[A_{ijk(Reading),\,t} - A_{ijk(Maths),\,t}] + \lambda(TC_{k(reading)} - TC_{k(maths)}) + (\mu_{j(reading)} - \mu_{j(maths)}) + (\eta_{i(reading)} - \eta_{i(maths)}) + (\varepsilon_{kl(reading)} - \varepsilon_{kl(maths)})$

Or, in a model of *changes* in test scores

(7) $\{[A_{ijk(Reading),\,t+1} - A_{ijk(Reading),\,t}] - [A_{ijk(Maths),\,t+1} - A_{ijk(Maths),\,t}]\} = \lambda(TC_{k(reading)} - TC_{k(reading)}) + (\mu_{j(reading)} - \mu_{j(maths)}) + (\eta_{i(reading)} - \eta_{i(maths)}) + (\varepsilon_{kl(reading)} - \varepsilon_{kl(maths)})$

So here we regress difference in child performance across subject on the difference in teacher characteristics (including contract status) across subject. If school level unobservables are not subject-specific, then μ_j drops out. Similarly if pupil-level unobservables are not subject specific (e.g. if students who are bright in one subject are generally also bright in other subjects), then η_i also drops out. If it is the case that children are innately better in reading than mathematics (or vice-versa) and this subject-specific ability is constant over time, then this will drop out in our value-added framework though if subject-specific ability changes over time (that is, pupils who are better are reading not only have higher levels, but higher *rates of change* in scores, then $(\eta_{i(reading)} - \eta_{i(maths)})$ will remain in the error term. This is a problem if $\text{cov}[(\eta_{i(reading)} - \eta_{i(maths)}),(TC_{k(reading)} - TC_{k(reading)}) \neq 0,$ as this will bias our estimate of the contractual teacher effect. This could be the case if regular teachers, due to their higher status, can choose to teach only the higher performing pupils for one subject, which is not possible here as there is only one class per grade in our sampled schools.

After estimating the causal impact of contract teachers we try to explain our findings, using three different approaches. Firstly, we look at the impact that contract teachers have on reducing class-size and alleviating multi-grade teaching. Secondly we use measures of teacher effort to investigate the proposition that renewable contracts induce higher levels of teacher effort. Finally we allow for differential effects of observable characteristics by teacher type, using a saturated model, as suggested by Derecho and Glewwe (2002). In a saturated model our estimations include both observed characteristics and their interaction with the contract teacher variable. By introducing interaction terms between our variable of interest (contract teacher dummy variable), and mean-centred values of all other observable characteristics, we can estimate the Average Treatment Effect of being taught by a contract teacher. A child with characteristics that are exactly average, in the average school with a teacher with average characteristics, will not deviate from the mean value for any variable – therefore all variables will equal zero with the

exception of the contract teacher variable. In addition to yielding the Average Treatment Effect of having a contract teacher, this method allows us to see the pathways through which the effect works. A full derivation of the model can be found in Appendix 2.

We are estimating the achievement equations on a sample of enrolled children only and, in principle, this could be a selected sample. Ideally one should use a sample selectivity correction approach. In practice, it is difficult to find convincing exclusion restrictions with which one could identify the selectivity term lambda using a Heckman selectivity correction model. However, primary school enrolment rates are high with more than 90% of primary age children in school in the two sample states. Thus, we do not expect selectivity to be too much of a problem.

Given the dominance of low scores in our data-set, and the subsequent skewness of the test-score distribution, we are likely to suffer from heteroskedasticity in our estimations. Indeed, even after controlling for this our model still fails Greene's (2002) test for group-wise heteroskedasticity. A consequence of this is that our inference is likely to be inefficient as our standard errors are too high, so we will understate significance. Given our high number of observations (8,185 falling to 3942 in the value-added specification) this is unlikely to be much of a problem. An alternative would be to estimate a non-linear model, such as a count model; however we then lose the ability to estimate using within-schools as a true fixed effects estimator for the negative binomial[6] model does not exist (Allison and Waterman 2002). As such, we prefer the linear estimator and accept the resulting inefficiency.

3. Findings

Due to some potentially important differences between the contracts of para teachers in Uttar Pradesh and Bihar, we estimate the achievement model for each state separately. The analysis is restricted to government schools only since contract teacher schemes exist only in government schools.

Uttar Pradesh

The main results for UP are presented in Table 2. The model pools both subjects (Hindi and Maths), both grades (2 and 4) and both time periods (i.e. surveys at the start and end of the school year) and we therefore include controls for subject, grade and time period. The dependent variable in all regressions is the overall z-score of achievement, using the mean of achievement test score in both subjects, for both grades and both time periods.

Our variable of main interest is the contractual status of the teacher (contract teacher=1; regular teacher=0). Columns 1 and 2 provide the OLS baseline and columns 3 and 4 present school Fixed Effects (FE) estimation. School FE implies within-school estimation where all school level factors (observed and

[6] A simple Poisson model is excluded as this assumes the mean and variance of the dependent variable are equal – this is not the case in our data, where the mean is approximately 1/10 of the variance. Thus the negative binomial model is the obvious choice.

unobserved) that influence student achievement, are controlled for. Thus school FE estimation corrects for any bias due to the potentially non-random assignment of contract teachers to particular schools. OLS and school FE equations are presented with and without controls, to highlight the effect – on the main variable of interest – of conditioning on teacher and school characteristics.

We briefly discuss other results before turning to our main variable of interest – the contract teacher dummy variable. In the OLS equation (column 2), school resources and textbook provision have large and statistically significant associations with child test scores, but mid-day meals and class size do not. However, these results do not represent causal effects. Looking at the school FE results, pupil achievement improves between grades: on average children in grade 4 score about half a SD higher than those in grade 2 (the base category). Boys outperform girls by 0.15 SD, a noticeable amount given that any selection bias in school enrolment is likely to favour girls' scores. Healthier children do better (as in Kingdon and Monk, 2010). Parental education and wealth (as measured by asset ownership) are significant predictors of achievement and private tuition has strong effects, with children who receive external tuition scoring over a quarter of a SD higher than those who do not.

In the school fixed-effects regression, male teachers lower achievement by 0.13 SD compared to being taught by a female teacher. Teachers with BA or higher qualifications have better performing pupils than those with only higher secondary qualifications or less (base category), but there is no discernable difference between teachers with Bachelor's and Master's qualifications. A teacher who completed his/her Higher Secondary exams in the first division (a proxy for the teacher's own cognitive skills) has higher performing pupils. We have not included the pre-service teacher training variable as that is highly collinear with the contract teacher dummy, the variable of most interest.[7]

Turning our focus to the primary question of this paper – the relative effectiveness of contract and regular teachers – it is seen that in the OLS achievement equation without controls (column 1), the contract teacher variable has a negative though insignificant coefficient but that the introduction of teacher and school characteristics in column 2 reverses the sign. A similar story emerges when moving from column 3 to 4, which introduces teacher characteristics in a school-fixed effects framework. After controlling for observed teacher characteristics and for all observed and unobserved school characteristics

[7] When we estimate using teacher training as an additional control (shown in Appendix 3) we find the contract teacher effect reduces somewhat (from 0.20 to 0.16 SD), and pupils of trained teachers surprisingly have significantly lower achievement (-0.19 SD). One would expect training to improve performance, thus teacher training here is most likely picking up differences in behaviour between teacher types, which are collinear with contractual status. As such, we prefer estimates without the training variable.

(column 4), contract teachers raise child test scores by about 0.21 SD compared to being taught by a regular teacher.

The increase in the coefficient on the contract teacher variable when we move from OLS (across-school) to School Fixed Effects (within-school) estimation is unsurprising: the OLS coefficient on the contract teacher variable is downward biased since contract teachers are generally more likely to be assigned to communities where households are more deprived. The correlation between 'proportion of para teachers in a school' and household wealth of children in the school is -0.16 and this is highly statistically significant (p=0.000)[8]. In other words, in across-school estimation, the contract teacher variable is partly 'picking up' the effect of community's deprivation.

School and Pupil Fixed Effects value-added models of achievement

Table 3 extends the analysis to more stringent models of the achievement production function. It presents two variants of the value added model, each of them first with school fixed effects and then with pupil fixed effects. Both of these pool subjects and grades, but not time period[9].

Column 1 estimates a School FE model with control for initial ability. Here the dependent variable is the z-score of achievement in a subject at the end of the school year, and it controls for z-score of achievement in that subject at the start of the school year. This furnishes the effect of being taught by a contract teacher after taking into account initial performance. Column 2 estimates a purer value-added model, where the dependent variable is the z-score of 'change in absolute pupil achievement in a subject over the school year'. This tells us how contract teachers affect the growth of cognitive skills over the school year.

Pupils in grade 4 learn more over the school year than those in grade 2, having value-added scores of 0.25 SD higher (column 2). This may be because the difficulty level of the tests is pitched at the type of competencies that are learnt better at the grade 4 stage in Uttar Pradesh.

Child and family variables remain largely unchanged, with the exception of paternal education which has a far lower effect in the value added than in the levels framework (column 4 of Table 2).

[8] At the child level, those taught by contract teachers are more deprived: the t-value of the contract-regular teacher difference in maternal years of education is 6.0, in paternal education is 6.9 and in household wealth is 2.9.

[9] In Table 3, there are 2053 children of grades 2 and 4 but, as there are two rows of data for each child (one for each subject), N should be double, i.e. 4106. Instead N is 3942. This is mainly because for 164 children, their mark is available only in one subject rather than both. Similarly, in Table 2 (which pools both surveys at the start and end of the school year), N should be double of 3942, i.e. it should be 7884 but instead it is 8185. This is mainly because for about 150 children, achievement mark in both subjects is available only for one time period, not both. However, the contract teacher results are virtually unchanged when we keep only children on whom we have test score in both subjects in both time periods.

Interestingly, while the coefficient on maternal education falls, it does so by far less and has a significant coefficient nearly 4 times the size on paternal education. This suggests that children of more educated mothers learn more throughout the school year, reflecting mothers' greater time with their offspring than fathers. The gender differential in value added score declines to 0.048 SD, but is still statistically significant, suggesting that the big gender gap in the levels regressions (of Table 2) was part of a steady divergence in learning throughout the years. The benefits from private tuition diminish when we control for prior ability (relative to column 4 in Table 2).

The positive contract teacher effect remains intact even after we control for prior ability. Controlling for initial ability yields a contract teacher effect of 0.140 SD (column 1) while in the value added model it is 0.208 SD (column 2). Given there is a 0.325 SD increase in learning over the school year (column 4 of Table 2), being taught by a contract teacher yields learning benefits equivalent to between $2/5^{ths}$ and $3/5^{ths}$ of a year in school. In another way of benchmarking its size, the contract teacher effect of between 0.14 and 0.21 SD is equal to the effect of between 5 and 7 years of mother's education (controlling for father's education).

Even in within-school estimation, the contract teacher variable is potentially endogenous. All the narratives of concern surrounding contract teacher schemes are based on the fear that contract teachers may be of *lower* ability and motivation since they are paid only one-quarter to one-third of the pay of regular teachers in UP and Bihar, and since their educational and professional qualification-requirements are lower than regular teachers'. Thus, if the school FE estimate suffered from endogeneity bias, it would mean that the estimated contract teacher effect is, if anything, downward biased due to such teachers' lower ability than regular teachers, and would imply that the true contract teacher effect is even higher than 0.21 SD.

Columns 3 and 4 re-estimate the achievement production function using the pupil fixed effects estimator, where identification comes entirely from differences in teacher-type across subject *within a pupil*, that is, when the same child is taught by a regular teacher for one subject and a contract teacher for another. This specification controls for all (subject-invariant) unobserved pupil characteristics. We would argue that in this estimator the teacher characteristics (including contract dummy variable) are not endogenous since there is nothing in the rules for hiring contract or regular teachers that favours one subject or another. Moreover, in any case, there is only one class of a given grade in our sample of schools (indeed about half the time two or more grades sit together in a class), and classes are not split by subject in the primary grades – thus a school cannot assign the students of a grade who are bright in a given subject to teachers who are bright in that subject; the whole class is taught as a unit, in both subjects.

Again we present two variants: column 3 regresses test score at the end of the school year on initial test score at the start of school year, and on teacher characteristics; column 4 presents a value-added equation, relating temporal change in test score to teacher characteristics. These two columns report our most stringent estimates of the contract teacher effect. We find a positive and large point estimate of the contract teacher effect (0.24 SD) in column 4, though it is statistically insignificant in both models (columns 3 and 4). There may not be enough within-pupil variation in teacher type across subject to precisely identify the effect of contract teachers.

Bihar

Having presented the results for UP, we now turn to the state of Bihar. The main results are presented in Table 4. There are strong achievement differences between grades in Bihar, with pupils in grade 4 scoring 1.023 SD higher than those in grade 2. This is double the achievement differential found in UP, suggesting a higher relative *rate* of learning between grades in Bihar than in UP (the *level* of learning is also higher in Bihar than in UP, see Appendix 1; this is also corroborated in the national ASER survey (2009) and in the NCERT survey (2005)). One potential explanation for higher learning levels is that Bihar students are much more likely to take private tuition (40% of the sample compared to 4% in UP, see Appendix 1). Another possible explanation is that while much of the cognitive skills tests are pitched at the grade 4 level of difficulty, in UP grade 4 pupils are more akin to grade 2 pupils in terms of their level of competency and that is why they exhibit lower levels of achievement *growth* – because the test is too difficult for them – while in Bihar grade 4 children are at the grade 4 level of competency and thus exhibit the sort of gain in learning over the school year that one might expect from a grade 4 child.

The differential between maths and language scores is greater in Bihar than UP, at nearly 0.20 SD (compared to 0.06 in UP). The gender gap is also nearly double, with boys outperforming girls within the same school by 0.26 SD. Measures of child health – illness and height – are significantly related to cognitive outcomes. Both maternal and paternal education is related to performance, though less so than in UP, and again maternal education has a stronger effect than paternal. The effect of household wealth is twice as strong as in UP though private tuition has a somewhat smaller effect. The majority of teacher characteristics are insignificantly correlated with student achievement other than teacher's gender and age, which have similar coefficients as in UP.

With regards our variable of most interest, moving from OLS to school FE estimation raises the contract teacher effect because in Bihar (as in UP), para teachers are more likely to be serving in the more deprived communities and the para teacher variable 'picks up' the effect of community deprivation in the OLS equation. In the School FE achievement equation conditioning on teacher characteristics, the contract teacher variable has a positive and weakly significant coefficient: pupils of contract teachers

score 0.069 SD higher than their regular teacher counterparts in the same school. This effect is substantially smaller than in UP (0.208), a point we return to below.

In Bihar a court ruling in 2006 stipulated that applicants with teacher training certificates should be given preference in contract teacher appointments even if they did not live locally (to the school). Many of the contract teachers appointed in 2006 in Bihar were thus individuals who possessed teacher training (often unemployed persons who had done teacher training many years ago). If we consider those appointed in 2006 and with pre-service training as a separate group to those who were appointed either pre-2006 or in 2006 without training, then we can classify Bihar contract teacher into three different types. Re-estimating the model (Table 5) with 'regular teacher' as the base category for teacher-type in all equations, we could not reject the null that the coefficients on the different contract teacher dummy variables are equal. That is, there is statistically no difference in the relative effectiveness of contract teachers with and without pre-service training (controlling for age, qualifications and gender). This calls into question the quality and usefulness of pre-service training.

School and Pupil Fixed Effects value-added models of achievement

In Bihar while the school FE estimate of the contract teacher effect is positive, it is only weakly significant. In Table 6 we test the robustness of this finding in four more models: firstly school FE with controls for initial achievement, secondly school FE using value-added achievement, and then these two repeated again using pupil fixed effects estimation.

We find that while the contract teacher effect is always positive, it is only weakly statistically significant in one specification. Our most stringent results are from the pupil-fixed effects specification where identification comes entirely from differences in scores across subjects within a pupil, i.e. it controls for any (subject-invariant) unobserved child-level characteristics. We find that a pupil's achievement in a subject that is taught by a contract teacher is higher than in a subject that is taught by a regular teacher (by between 0.06 and 0.07 SD) but that the effect is at best only weakly significant.

Thus, our results suggest that contract teachers are substantially more effective than regular teachers in UP and weakly more effective than regular teachers in Bihar. This raises the question why? To answer this question we look at two possible avenues – the effect that contract teachers have on changing classroom organisation (such as multi-grade teaching and class-size) and differences in behaviour by teacher type.

4. Why are contract teachers equally, or more effective than regular teachers?

a. Changes in class-size and multi-grade teaching

One way through which contract teachers may have beneficial effects on child learning is by lowering pupil-teacher ratios and reducing or eliminating multi-grade teaching. Indeed, this is one of the officially

stated rationales for the hiring of contract teachers. Schools with more contract teachers can be expected to have lower pupil-teacher ratios and use more mono-grade teaching. Table 7 shows the school-level correlation between the number of contract teachers in a school on the one hand, and pupil-teacher ratio and multi-grade teaching on the other. Given the marked differential between the *official* pupil-teacher ratio (defined as the ratio of the total number of enrolled pupils to appointed teachers in the school) and the *actual* observed pupil-teacher ratio (defined as the number of teachers and pupils present when the school was visited), we report both measures. A school is defined as being multi-grade when the number of classes observed was less than the number of grades in the school. Table 7 shows that the number of contract teachers in a school is significantly negatively correlated with both the official and the actual pupil-teacher ratio in both states, suggesting that schools with higher numbers of contract teachers do indeed have lower class sizes. In Bihar, number of contract teachers in a school is significantly negatively correlated with the incidence of multi-grade teaching.

Is it the case then that the estimated contract teacher 'effect' is really an effect of reduced class-size and improved classroom organisation? To examine this issue, in Table 8 we present OLS and School FE estimation of achievement, controlling for class-size and mono-grade teaching. We can control for actual class-size and mono-grade even within a school as these can vary between grades. Given the identification problems when using OLS regressions, we prefer School FE estimates, but given the *across school* correlations highlighted in Table 7, we also report OLS to show there that even in an *across school* regression, the contract teacher effect is independent of class-size and mono-grade teaching. The class-size (pupil-teacher ratio, PTR) effect is wholly insignificant in the OLS regression and weakly significant with a tiny coefficient in the fixed effects estimation (columns 2 and 5) in both states. Mono-grade teaching has a large positive association with achievement in UP (column 6), but is perversely negative in Bihar.

Most importantly for our question, neither the inclusion of class size, nor of control for mono-grade teaching, significantly changes the coefficient of the contract teacher variable. Thus, while contract teachers lower class-size (in both states) and lessen multi-grade teaching (in Bihar), this does not appear to be driving the contract teacher effect.

b. Changes in teacher effort

An additional possible explanation is that contract teachers, due to their short-term insecure contracts which can be terminated, face greater accountability pressures and thus exhibit more effort than regular teachers. One way of measuring teacher effort is through the teachers' absence rate. Certainly in UP contract teachers display noticeably lower (about half) absence rates than regular teachers. In Table 9 we re-estimate the school-fixed effect achievement equation (Column 4 of Table 2) but now also control for a

number of measures of teacher effort, including whether or not they report spending time supporting weak children and the proportion of time they spend in beneficial activities in the average school day. Given the weak significance of the contract teacher effect in Bihar, we report estimates for UP only, though inclusion of teacher effort measures has similar effects in Bihar as in UP. Each additional control is evaluated first without teacher type (columns 2, 4 and 6) and then with teacher type (columns 3, 5 and 7).

Table 9 shows that the contract teacher effect is very robust to inclusion of controls for teacher effort. Statistically there is no difference among the point estimate between all specifications. This result is robust to allowing non-linearities in the relationship between teacher effort and achievement (not shown).

Column (2) shows that children whose teacher is absent more frequently score lower. Including both teacher absence and the contract teacher variable, we find the coefficient on absence halves (from -0.125 to -0.0595) but the contract teacher effect falls only slightly and remains significant. This can arise if variation in absence rates in mostly across-teacher types, rather than within-teacher types.

Column (4) reports the effect of teacher's time-on-task. The measure used is a composite index, as detailed in the note to Table 9. The variable itself is insignificantly associated with child achievement and its inclusion does not change the contract teacher effect substantially or statistically significantly. Column (6) shows that child achievement benefits strongly from having a teacher who supports weak pupils, as explained in Table 9. This is consistent with Bourdon et al.'s (2007) findings that contract teachers are particularly effective when teaching lower ability pupils. The effect diminishes slightly when we control for teacher type (column 7), as contract teachers are more likely to report supporting weak pupils (17% compared to 6% for regular teachers). Importantly for our main question, inclusion of this measure of teacher effort does not reduce the contract teacher effect.

We conclude that the positive contract teacher effect is not explained by the dimensions of teacher effort that are available in our data set. One potential explanation of the contract teacher effect is as follows: the lower salaries of contract teachers may imply that only persons intrinsically motivated towards teaching children take these low paid jobs, whereas regular teachers are individuals who are attracted more by the high salaries of regular teacher posts but have less intrinsic motivation for teaching. However, the activities inspired by any such higher motivation of contract teachers (that lead them to be more effective as teachers) are not adequately captured in the measures of teacher effort available to us.

c. Differential effects of observables by teacher type

The previous models have shown that the contract teacher effect is both positive and robust to the inclusion of the available measures of effort. While it is possible that these effects are driven by unobserved characteristics of contract teachers, notably higher non-measurable aspects of effort, it is also

possible that it partly may be due to differential effects of observable characteristics by teacher type. To investigate this, we estimate a saturated model, where our estimations include both observed characteristics, and their interaction with the contract teacher variable. By introducing interaction terms between our variable of interest (contract teacher dummy variable), and mean-centred values of all other observable characteristics, we can estimate the Average Treatment Effect (ATE) of being taught by a contract teacher (see methodology section). A child with characteristics that are exactly average, in the average school with a teacher with average characteristics, will not deviate from the mean value for any variable – therefore all variables will equal zero with the exception of the contract teacher variable.

In addition to this, the coefficients on the interaction terms tell us *how* contract teachers affect child learning. A significant coefficient on these terms shows that the interaction between contract teachers and these inputs leads to significantly different outcomes for pupils taught by contract teachers when compared to those taught by regular teachers. This should allow us to open the black box of why a contract teacher is equally or more effective than a regular teacher.

In both UP and Bihar the ATE of the contract teacher variable is small and statistically insignificant. This shows that the average treatment effect of having a contract teacher is zero – that is, contract teachers are no less and no more effective than regular teachers after controlling for all possible interaction effects.

An F-test of insignificance of the interaction terms is decisively rejected in both states; interactions between contract teachers and our observable characteristics have a significant effect on learning outcomes.

In both states male contract teachers are more effective than male regular teachers. Overall, in schools with more than the average male/female teacher ratio, we find a positive male contract teacher effect relative to male regular teachers. In UP, male contract teachers are more effective than female regular teachers, while in Bihar they are not. This suggests that in UP the contract teacher effect completely mitigates the negative effect of being a male teacher, while in Bihar it reduces it, but male teachers (regardless of contractual type) are still less effective than female teachers.

In a school with a male/female ratio that was 10% higher than the average, a child taught by a regular teacher would score 0.038 SD lower than being taught by a female regular teacher. If taught by a contract teacher they would score 0.0373 SD higher than if they were being taught by a male regular teacher (or 0.0035 SD higher than a female regular teacher). As the proportion of males in the school increases, the differential between being taught by a regular male teacher and a regular contract teacher increases.

Contract teachers appear to mitigate the negative effects of below-average health, both in terms of long term measures such as child height and short term effects of absence through illness. Children with below average height and fathers with below average levels of education gain from having a contract

teacher in UP. Given that paternal education is likely to have more indirect effects than maternal education (which has equal effects for both teacher types) – fathers are less likely to be active in the day to day education of the child, more in determining attitudes to schooling and school choice – this may suggest that contract teachers reduce the negative impact of coming from families with lower SES. Also, a child who has a contract teacher and is ill for more than 4 days in the last 3 months would lose 0.09 SD relative to his healthier peers, while a child in the same situation with a regular teacher would have a mark 0.24 SD lower than his healthier peers.

In Bihar, aside from teacher's gender, the only other significant differential effect is through lowering the benefits of receiving private tuition. Given that time-on-task is substantially lower in Bihar than UP (with teachers spending approximately 111 minutes teaching compared to 187 in UP), private tuition is far more pervasive, being undertaken by 40% of our sample of Bihar children. It appears that having a contract teacher narrows the achievement gap between those who take private tuition and those who do not.

In both states contract teachers appear to mitigate the effects – on test scores – of being from a disadvantaged background, be it having below averagely educated father (in UP), health problems (in UP) or not being able to take private tuition (Bihar). This is consistent with the fact that contract teachers are closer in terms of social standing to their pupils. Regular teachers, who enjoy salaries far above the average earnings in the areas they teach in, may consider under-privileged pupils less capable, and may neglect struggling students. The findings that contract teachers benefit weaker or lower-achieving children are supported by descriptive data from the teacher questionnaire based on teachers' opinions. The results (not presented) show that regular teachers are 7 percentage points more likely (than contract teachers) to agree 'fully' or agree 'quite a lot' with the statement that 'schedule caste and schedule tribe children are generally less attentive or less motivated towards studies than other children', and this difference between regular and contract teachers' opinions is statistically significant at the 6% level of significance.

The saturated model suggests that while the ATE effect of a contract teacher effect is roughly zero, contract teachers have significant interaction effects with observables. Most notably they are good for increasing the efficiency of male teachers, and also appear to lessen the achievement disadvantage for children of lower socio-economic status.

5. The relative cost of contract teachers

The previous sections have focussed on the relative effectiveness of regular and contract teachers. However, this is only one half of the discussion. To complete the picture we shift our attention to the remuneration of teachers and calculate the 'teacher salary cost per achievement point'. Our estimations

suggest that pupils with contract teachers score 0.21 SD higher in Uttar Pradesh, and 0.063 SD higher in Bihar. This translates into an average absolute-score increase of 8.4 marks in UP and 3.7 marks in Bihar, taking the average student from 25.5 marks to 33.9 in UP and from 63.4 marks to 67.1 marks in Bihar. This translates to a 33% increase and 6% increase in marks in UP and Bihar respectively.

To illustrate this point, Table 11 shows the relative cost per achievement point, of regular and contract teachers in each state. The ratio of regular teacher pay to contract teacher pay is 3.97 in UP and 2.65 in Bihar. However, when we calculate the cost per *predicted* achievement point (taken from the average child taught by each teacher type), this ratio increases to 5.27 in UP and 2.80 in Bihar. So UP's raw ratio of regular: contract teacher costs (3.97) increases to a standardized ratio of 5.27 when we consider the true cost (in terms of cost-per-predicted-achievement point).

It may be that regular teachers are paid higher than contract teachers to reward them for other favourable characteristics. For a more accurate comparison, the influence of these characteristics must be taken into account. Table 12 reports OLS and School-Fixed effects regressions of the log of teacher pay. We use as controls the teacher characteristics used in the achievement production functions earlier, but the results are robust to additional controls for teachers' caste and religion. We use data from government primary schools only, as in the achievement analysis in the rest of the paper.

Our model has high explanatory power. The average achievement level of children in the school is an insignificant determinant of teacher salaries in both states, highlighting the absence of performance related pay. The age earnings profile is twice as steep in Bihar as in UP. In the main, age and teacher type are the only significant determinants of teacher salary in these public sector schools. In neither state are there wage returns to educational qualifications, despite the positive influence they have on achievement. In all estimates the coefficient on male gender is positive and around 5-6%, though the effect is only significant for Bihar. This positive coefficient contrasts with the consistently significant negative coefficient we find for the effect of male teachers on achievement. In Bihar we find that teacher training yields a wage return of 8%, even though it is uncorrelated with higher child achievement (Table 5) and may even lower achievement (footnote 7).

Contract teachers are paid far less in both states even after controlling for characteristics (i.e. when we compare regular and contract teachers of the same age, gender and qualifications). In UP the *ceteris paribus* contract teacher wage is approximately 33% of the regular teacher's wage and in Bihar it is approximately 56%[10]. This translates to regular teachers earning 3.06 times more than (otherwise comparable) contract teachers in UP, and 1.78 times more in Bihar.

[10] This is calculated by taking the exponential of the regular teacher's wage (given by the constant) and the contract teacher's wage (constant minus the contract teacher effect). This is likely to be an underestimate, as contract teachers are younger than regular teachers. After taking this into account the ratio is 3.59 in UP.

The structure of teacher pay in the government school sector is inefficient since it does not reward teaches for possessing characteristics that raise learning (in achievement equations). Female teachers are paid less despite raising student achievement, trained teachers are rewarded with higher pay despite no increase in student achievement from teacher training, and there is no performance related pay: teachers are not paid more if their students have higher achievement This is compounded by the fact that contract teachers are seriously underpaid relative to regular teachers of the same observed characteristics, despite producing higher pupil achievement.

6. Conclusions

This paper sought to measure the relative effectiveness and costs of regular and contract teachers in two Indian states. We used a number of models of the education production function to identify the causal effect of contract teachers. In all models we find that contract teachers do no worse than regular teachers, and indeed may be more effective than regular teachers. There is no evidence that the contract teacher effect is a class-size effect, i.e. that contract teachers appear more effective because they work with smaller classes or mono-grade classes.

Contract teachers are generally more likely to teach in more deprived schools and this may lead to an incorrect conclusion regarding their effectiveness. After controlling for all school factors (in a School Fixed Effects regression) as well as for a rich array of pupil and teacher characteristics, contract teachers in UP are more effective than regular teachers. Controlling for all unobserved pupil factors confirms a positive contract teacher effect but it is not precisely estimated. A reason why contract teachers apply greater effort than regular teachers is plausibly due to the insecure annually renewable nature of their contracts. Given this uncertainty they are liable to exhibit more effort, which could lead to higher child outcomes. However, the fact that much of the contract teacher effect remains even after we take their lower absence rates and other measures of effort into account suggests that they apply greater effort in dimensions other than being present in school and the other dimensions captured here.

In Bihar, contract teachers do not face strong accountability[11], yet are still no less effective (indeed are weakly more effective) than regular teachers. This holds irrespective of the type of contract teacher. This shows that it is something intrinsic in the contracting of para teachers that leads them to be equally or more effective than regular teachers, despite their lack of training and experience, and their far lower pay. In Bihar, there is a clause in contract teacher contracts saying that appointments can be reviewed every three years, creating some weak accountability pressures. While these pressures are clearly not strong enough to elicit a difference in contract teachers' school attendance habits, it may lead

[11] At least in the year of the survey (2007-08) they did not. In July 2009, the Bihar state government announced that it would test contract teachers before re-confirming their jobs. Teachers would have to gain at least 45% marks in the test to be reconfirmed in their jobs.

to a weak increase in effort-levels in dimensions that we have not been able to capture here. It could be that contract teachers are of a different type than regular teachers; for example, lower salaries of contract teachers may imply that only persons intrinsically motivated towards teaching children take these low paid jobs, whereas regular teachers are individuals attracted more by the high salaries of regular teacher posts but have less intrinsic motivation for teaching.

A saturated model suggests that part of the contract teacher effect is due to contract teachers mitigating the negative effects of being socially disadvantaged, possibly due to the lesser social distance of contract teachers to their pupils, relative to regular teachers. This is supported by the fact that contract teachers devote more time supporting weak children in schools. In conjunction with the fact that contract teachers live closer to school this may induce more effort by making teachers more accountable to parents. That contract teachers are less socially-distant from their students is supported by Kingdon (2010) which estimates that in 2005 the ratio of teacher pay to state per capita income in UP was 7.3, i.e. regular teachers are 7 times as well off as the average student they teach, a great economic distance, which is likely to be even greater in *rural* UP since rural per capita incomes are around one-third of urban incomes. Kingdon concludes that "When teachers are so much better-off than the students, they can look down on students with disdain since children in government schools typically come from poorer than average backgrounds in any case, and may come to school shabby, unclean and underfed".

In conclusion, it appears that by making teachers more accountable their performance improves. This is partly due to contract teachers mitigating the negative effect of child socio-economic disadvantage (possibly a product of being more local to the school) and partly due the 'para' teacher contract making male teachers noticeably more effective (a product of renewable contracts). The effects are strongest when the accountability is strongest, suggesting that yearly renewal of teacher contracts may lead to improved performance. Even when accountability is weak, as in the case of Bihar, such weak accountability is sufficient to ensure that contract teachers are weakly more effective or, at worst, no less effective than regular teachers.

Not only are contract teachers more effective than regular teachers, they also offer far better value-for money. Using raw-salary differentials, regular-teachers have a cost per predicted achievement point that is 5.27 times higher than contract teachers in UP and 2.80 times higher than contract teachers in Bihar. Even after controlling for other wage-determining characteristics, contract teachers are paid just 33% of a regular teachers wage in UP, and 56% of the wage in Bihar, a fact at odds with our conclusions regarding their relative effectiveness.

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Table 1: Descriptive statistics of teachers, by state and teacher type

	UP			Bihar		
	Regular	Contract	t-test of difference	Regular	Contract	t-test of difference
General Characteristics						
Male	0.49	0.52	-0.31	0.84	0.55	-3.90***
Age in years	44.35	27.09	-11.88***	42.05	29.27	-10.33***
Tenure	6.47	3.29	- 4.62***	6.73	2.71	-2.82***
Salary (Rs per month)	11163	2988	-26.52**	10636	4195	-18.06**
Education and Training						
BA degree	0.23	0.49	2.91***	0.27	0.34	1.01
MA degree	0.30	0.19	-1.45	0.30	0.07	-4.52***
First Division	0.16	0.16	0.02	0.23	0.55	4.13***
Received training	0.95	0.34	-8.01***	0.84	0.39	-6.29***
Teacher Effort						
Absence rate	0.23	0.11	-3.07***	0.16	0.21	1.70*
Proportion of the working day teaching	0.75	0.84	2.82***	0.76	0.84	-2.41***
Supports weak students	0.08	0.15	1.14	0.16	0.32	2.30**

Note: Tenure is the number of years a teacher has worked at the current school. First Division indicates whether the teacher passed her/his Higher Secondary examinations with First Division marks (yes=1, no=0) 'Proportion of the working day teaching' is the teacher's self-report of the proportion of the typical school day that she/he spends in teaching (as opposed to non-teaching) activities. This table reports the characteristics of teachers that teach grades 2 and 4, and not of all teachers of grades 1 through 5 in SchoolTELLS survey's sample schools. Hence these mean characteristics may differ somewhat from those reported elsewhere, e.g. in Kingdon and Sipahimalani-Rao (2010).

Table 2: Achievement Production Function, Uttar Pradesh

	OLS		School Fixed Effects	
	(1)	(2)	(3)	(4)
	No teacher controls	Teacher controls	No teacher controls	Teacher controls
Grade 4	0.447***	0.406***	0.508***	0.536***
	(5.27)	(4.35)	(16.39)	(16.40)
Hindi	0.0449*	0.0512*	0.0587***	0.0658***
	(1.85)	(2.00)	(3.29)	(3.64)
Survey Number	0.309***	0.323***	0.324***	0.325***
	(8.27)	(9.13)	(17.29)	(17.36)
Child Characteristics				
Age in years	0.0307	0.0390**	0.0650***	0.0683***
	(1.63)	(2.22)	(7.83)	(8.22)
Male	0.134***	0.155***	0.157***	0.147***
	(2.91)	(3.81)	(8.34)	(7.80)
Height (cm)	0.0168***	0.0162***	0.0131***	0.0132***
	(6.40)	(6.73)	(10.76)	(10.84)
Illness	-0.0666*	-0.0958***	-0.0882***	-0.0922***
	(-1.90)	(-3.21)	(-4.63)	(-4.85)
Father's education	0.0245***	0.0259***	0.0215***	0.0210***
	(4.62)	(5.08)	(8.41)	(8.25)
Mother's education	0.0255***	0.0271***	0.0284***	0.0281***
	(3.14)	(3.34)	(6.86)	(6.81)
Asset index (ln)	0.0726***	0.0464*	0.0296**	0.0319***
	(3.14)	(1.99)	(2.42)	(2.62)
Takes tuition	0.229**	0.257***	0.269***	0.270***
	(2.50)	(3.26)	(5.65)	(5.68)
Teacher characteristics				
Contract teacher	-0.105	0.105	-0.00609	0.208***
	(-1.09)	(0.88)	(-0.19)	(4.29)
Age		0.0111***		0.0107***
		(2.84)		(5.56)
Male		-0.0251		-0.131***
		(-0.40)		(-4.56)
BA		0.0198		0.0996***
		(0.27)		(2.66)
MA		-0.0388		0.0960**
		(-0.51)		(2.51)
First Division		0.0738		0.153***
		(0.78)		(3.88)
School characteristics				
Textbook ratio		0.425***		
		(3.65)		
Resource index		0.0995***		
		(2.96)		
Meal always		0.0975		
		(1.40)		
Pupil-teacher ratio		0.000582		
		(0.42)		
Pupils	2330	2330	2330	2330
N	8185	8165	8185	8185
No. of schools			62	62
R^2	0.252	0.290	0.275	0.280

Notes: Model also includes dummies for missing observations in parental education, private tuition and child health. OLS regressions control for clustering within schools and for heteroskedasticity. Constant included but not shown

Table 3: Achievement Production Function, Uttar Pradesh: School and Pupil Fixed Effects value added

	School Fixed Effects		Pupil Fixed Effects	
	(1) controls initial ability	(2) value added model	(3) controls initial ability	(4) value added model
Z-Score in visit one	0.919***		0.504***	
	(71.18)		(21.91)	
Grade 4	0.198***	0.254***		
	(5.74)	(4.66)		
Hindi	0.0650***	0.101***	0.0663***	0.0968***
	(3.46)	(3.34)	(4.93)	(4.02)
Child characteristics				
Age in years	0.0116	0.0117		
	(1.31)	(0.82)		
Male	0.0478**	0.0624**		
	(2.44)	(1.98)		
Height (cm)	0.00112	-0.0000787		
	(0.84)	(-0.04)		
Illness	-0.0613***	-0.0858***		
	(-3.15)	(-2.74)		
Father's education	0.00550**	0.00639		
	(2.06)	(1.49)		
Mother's education	0.0207***	0.0305***		
	(4.74)	(4.34)		
Asset index (ln)	0.0120	0.0164		
	(0.94)	(0.79)		
Takes tuition	0.102**	0.131		
	(2.06)	(1.64)		
Teacher characteristics				
Age	0.00253	0.00278	0.00585	0.0160**
	(1.27)	(0.87)	(1.37)	(2.10)
Male	-0.0877***	-0.130***	-0.0823	-0.190*
	(-2.95)	(-2.72)	(-1.45)	(-1.86)
BA	0.0187	0.0185	0.0469	0.0929
	(0.48)	(0.29)	(0.61)	(0.68)
MA	0.00281	-0.00904	0.0675	0.219*
	(0.07)	(-0.14)	(0.91)	(1.65)
First Division	-0.0205	-0.0582	0.00542	0.0864
	(-0.50)	(-0.88)	(0.07)	(0.67)
Contract teacher	0.140***	0.208**	0.0372	0.243
	(2.80)	(2.57)	(0.36)	(1.31)
Pupils	2053	2053	2053	2053
N	3942	3942	3942	3942
No. of schools or pupils	62	62	2053	2053
R^2	0.678	0.0309	0.216	0.0116

Notes: Model also includes dummies for missing observations in parental education, private tuition and child health. Constant included but not shown. t statistics in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 4: Achievement Production Function, Bihar

	OLS (across-school)		School Fixed Effects	
	(1)	(2)	(3)	(4)
	no teacher controls	teacher controls	no teacher controls	teacher controls
Grade 4	0.931***	0.925***	1.023***	1.035***
	(16.83)	(14.99)	(39.06)	(37.62)
Hindi	0.184***	0.176***	0.187***	0.200***
	(7.64)	(6.81)	(9.75)	(10.00)
Survey Number	0.281***	0.276***	0.288***	0.287***
	(12.56)	(12.32)	(14.62)	(14.60)
Child characteristics				
Age in years	0.0352**	0.0358**	0.0218**	0.0219**
	(2.50)	(2.61)	(2.56)	(2.56)
Male	0.269***	0.269***	0.258***	0.257***
	(7.36)	(7.20)	(13.07)	(13.01)
Height (cm)	0.00348*	0.00312	0.000943	0.000962
	(1.81)	(1.61)	(0.75)	(0.77)
Illness	-0.0646**	-0.0731***	-0.0560***	-0.0558***
	(-2.22)	(-2.66)	(-2.87)	(-2.86)
Father's education	0.00873	0.00939*	0.0133***	0.0134***
	(1.63)	(1.73)	(4.90)	(4.94)
Mother's education	0.0266***	0.0268***	0.0239***	0.0237***
	(3.53)	(3.57)	(6.74)	(6.71)
Asset index (ln)	0.0798***	0.0778***	0.0637***	0.0629***
	(3.27)	(3.32)	(4.99)	(4.93)
Takes tuition	0.284***	0.279***	0.187***	0.190***
	(6.77)	(6.85)	(8.54)	(8.66)
Teacher characteristics				
Contract teacher	-0.00404	-0.0293	0.0322	0.0688*
	(-0.09)	(-0.53)	(1.09)	(1.92)
Age		-0.00229		0.00357**
		(-0.87)		(2.15)
Male		0.0311		-0.0619**
		(0.59)		(-2.11)
BA		-0.0338		-0.0280
		(-0.68)		(-0.95)
MA		-0.000797		0.0343
		(-0.01)		(0.78)
First Division		0.00670		0.0197
		(0.17)		(0.77)
School characteristics				
Textbook ratio		0.0837		
		(0.59)		
Resource index		0.0280		
		(1.46)		
Meal always		-0.0869		
		(-0.74)		
Pupil-teacher ratio		0.00131		
		(1.05)		
Pupils	2003	2003	2003	2003
N	6774	6678	6774	6774
No. of schools			71	71
R^2	0.362	0.362	0.360	0.362

Notes: Model also includes dummies for missing observations in parental education, private tuition and child health. OLS regressions control for clustering within schools and for heteroskedasticity. Constant included but not shown.

Table 5 : Differentiating by type of contract teacher, Bihar – School FE

	(1) Contract	(2) Contract with and without training	(3) Full differentiation
Contract teacher	0.0688*		
	(1.92)		
Contract teacher with no training		0.0680	0.0694
		(1.47)	(1.50)
Contract teacher with training		0.0691*	
		(1.80)	
Contract teacher appointed pre-2006			0.0790*
			(1.78)
Contract teacher appointed post-2006 without training			0.0629
			(1.54)
F-test equal coefficients		0.000723	0.0982
P-value		0.979	0.906
N	6774	6774	6774
No. of schools	71	71	71
R^2	0.362	0.362	0.362

Note: The equations include all child, home background and teacher variables included in the previous achievement tables but we do not show the results.

Table 6: Achievement Production Function Bihar – School and Pupil Fixed Effects value added

	School Fixed Effects		Pupil Fixed Effects	
	(1) controls initial ability model	(2) value added model	(3) controls initial ability	(4) value added model
Z-Score in visit 1	0.841***		0.469***	
	(60.33)		(19.07)	
Grade 4	0.0869***	-0.140***		
	(2.67)	(-2.83)		
Hindi	0.0491**	0.0334	0.108***	0.0269
	(2.32)	(0.93)	(6.55)	(0.88)
Child characteristics				
Age in years	-0.00595	-0.0182		
	(-0.66)	(-1.19)		
Male	0.0686***	0.0525		
	(3.26)	(1.48)		
Height (cm)	-0.000219	-0.000466		
	(-0.17)	(-0.21)		
Illness	-0.0169	-0.0161		
	(-0.80)	(-0.44)		
Father's education	0.00464	0.00477		
	(1.60)	(0.97)		
Mother's education	0.00948**	0.0105		
	(2.52)	(1.64)		
Asset index (ln)	0.0378***	0.0497**		
	(2.81)	(2.17)		
Takes tuition	0.115***	0.157***		
	(4.94)	(3.96)		
Teacher characteristics				
Age	0.00390**	0.00586**	0.00344**	0.00299
	(2.23)	(1.96)	(2.14)	(0.97)
Male	0.0268	0.0664	-0.0234	0.0208
	(0.86)	(1.25)	(-0.76)	(0.35)
BA	0.00317	0.0117	0.0597*	0.0576
	(0.10)	(0.22)	(1.84)	(0.92)
MA	-0.0797*	-0.157**	-0.0816*	-0.0788
	(-1.72)	(-1.98)	(-1.69)	(-0.85)
First Division	0.0251	0.0368	0.0847***	0.110**
	(0.93)	(0.80)	(3.51)	(2.38)
Contract teacher	0.0384	0.0535	0.0620*	0.0682
	(1.01)	(0.83)	(1.79)	(1.03)
Pupils	1819	1819	1819	1819
N	3317	3317	3317	3317
No. of schools or pupils	71	71	1819	1819
R^2	0.673	0.0260	0.276	0.00895

Notes: Model also includes dummies for missing observations in parental education, private tuition and child health. Constant included but not shown

Table 7: Univariate correlations between pupil-teacher ratios, multi-grade teaching and Contract teachers

	UP		
	PTR Official	PTR Actual	Multi-grade teaching
Number of contract teachers appointed to school	-0.172 (0.0065)	-0.1262 (0.0475)	0.0311 (0.6227)
	Bihar		
	PTR Official	PTR Actual	Multi-grade teaching
Number of contract teachers appointed to school	-0.4793 (0.000)	-0.1382 (0.0207)	-0.3622 (0.000)

Note: Correlations evaluated using information from all four visits. Notes: Spearman's rank correlations shown, p-values in brackets

Table 8: Achievement Production Function with controls for changes in pupil-teacher ratios and multi-grade teaching

			UP			
	OLS			School FE		
	(1)	(2)	(3)	(4)	(5)	(6)
Contract teacher	0.104	0.105	0.118	0.208***	0.203***	0.217***
	(0.85)	(0.88)	(0.95)	(4.29)	(4.17)	(4.46)
Pupil-teacher ratio		0.000582			0.00118*	
		(0.42)			(1.69)	
Mono-grade class			-0.0946			0.373***
			(-1.47)			(3.36)
Pupils	2330	2330	2330	2330	2330	2330
N	8185	8165	8185	8185	8165	8185
No. of schools				62	62	62
R^2	0.289	0.290	0.290	0.280	0.280	0.282
			Bihar			
Contract teacher	-0.0326	-0.0293	-0.0325	0.0688*	0.0758**	0.0807**
	(-0.60)	(-0.53)	(-0.59)	(1.92)	(2.10)	(2.25)
Pupil-teacher ratio		0.00131			0.00157**	
		(1.05)			(2.28)	
Mono-grade class			0.0228			-0.199***
			(0.40)			(-3.94)
Pupils	2003	2003	2003	2003	2003	2003
N	6774	6678	6774	6774	6678	6774
No. of schools				71	71	71
R^2	0.364	0.362	0.365	0.362	0.362	0.363

Note: All equations control for teacher, child and home background characteristics but these are not shown. OLS regressions control for clustering within schools and for heteroskedasticity. Constant included but not shown. *t* statistics in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 9: Achievement Production Function with controls for teacher effort and teaching style, Uttar Pradesh

	(1) Contract Teacher	(2) Teacher absence	(3) Absence and contract teacher	(4) Time-on-task	(5) Time on task and contract teacher	(6) Support weak pupils	(7) Support weak pupils and contract teacher
Contract teachers	0.208***		0.200***		0.226***		0.207***
	(4.29)		(4.00)		(4.46)		(4.20)
Absence rate		-0.133*	-0.0595				
		(-1.71)	(-0.75)				
Time-on-task				0.0281	-0.0175		
				(0.65)	(-0.40)		
Supports weak pupils						0.162***	0.143***
						(3.33)	(2.93)
Pupils	2330	2330	2330	2330	2330	2330	2330
N	8185	8185	8185	8185	8185	8185	8185
No. of schools	62	62	62	62	62	62	62
R^2	0.280	0.278	0.280	0.278	0.280	0.279	0.281

Note: All equations control for teacher, child and home background characteristics but these are not shown. "Time on task" is a composite index measuring the teacher's self-reported percentage of time devoted to teaching, prayer assembly, supervision of games and preparation for teaching. "Support weak pupils" is defined as having spent special time to help weak children in at least eight of the last ten days.

Table 10: Saturated School Fixed Effects Model with Contract teacher interactions

	Uttar Pradesh		Bihar	
	Regular Teachers	Additional interaction effect of Contract teacher	Regular Teachers	Additional interaction effect of Contract teacher
Grade 4	0.360***	0.118	0.839***	0.214**
	(5.49)	(1.46)	(10.93)	(2.51)
Hindi	-0.0264	0.110**	0.252***	-0.0821
	(-0.60)	(2.31)	(5.48)	(-1.59)
Survey Number	0.399***	-0.121**	0.278***	0.0198
	(8.59)	(-2.41)	(7.01)	(0.44)
Child characteristics				
Age in years	0.0398*	0.0231	0.0921***	-0.0847***
	(1.94)	(1.06)	(4.92)	(-4.02)
Male	0.0944**	0.0669	0.235***	0.0268
	(2.17)	(1.41)	(5.82)	(0.58)
Height (cm)	0.0107***	-0.00706*	0.0106**	-0.00530
	(2.91)	(-1.78)	(2.23)	(-1.02)
Illness	-0.214***	0.169***	-0.0394	-0.0196
	(-4.91)	(3.55)	(-0.99)	(-0.43)
Father's education	0.0324***	-0.0148**	0.0168***	-0.00374
	(5.99)	(-2.44)	(2.99)	(-0.58)
Mother's education	0.0373***	-0.0134	0.0269***	-0.00307
	(3.90)	(-1.23)	(3.60)	(-0.36)
Asset index (ln)	0.0504*	-0.0260	0.0362	0.0346
	(1.74)	(-0.83)	(1.35)	(1.14)
Takes tuition	0.321**	-0.0351	0.269***	-0.112**
	(2.48)	(-0.25)	(6.01)	(-2.21)
Teacher characteristics				
Age	0.00948***	-0.0125**	0.000728	0.00524
	(3.21)	(-2.30)	(0.27)	(1.44)
Male	-0.338***	0.373***	-0.192**	0.170**
	(-6.20)	(6.03)	(-2.44)	(2.03)
BA	0.0323	0.0676	0.105	-0.130
	(0.48)	(0.89)	(1.45)	(-1.60)
MA	0.0875	0.0302	0.155**	-0.161
	(0.96)	(0.28)	(2.23)	(-1.63)
First Division	0.0304	0.0875	-0.0482	0.0877
	(0.33)	(0.92)	(-0.77)	(1.25)
Contract teacher	0.0165		-0.0108	
	(0.25)		(-0.21)	
_cons	-0.0455		0.0167	
	(-0.76)		(0.36)	
N	8185		6772	
No. of groups	62		71	
R^2	0.297		0.370	
F_diff	5.412		2.513	
P_diff	8.95e-16		0.0000831	

Table 11: The relative cost of regular and para teachers

	UP			Bihar		
	Regular Teachers (a)	Contract teachers (b)	Ratio (c = a/b)	Regular Teachers (d)	Contract teachers (e)	Ratio (f = d/e)
Average Salary (Rupees)	11843	2985	3.97	11194	4232	2.65
Predicted Mean Achievement Score	25.49	33.88	0.75	63.37	67.11	0.94
Cost per predicted achievement point (Rupees)	464.61	88.10	5.27	176.65	63.06	2.80

Notes: Predicted mean achievement score is calculated following the School Fixed Effects regression of (column 4) in table 2, holding all variables at their means with the exception of contract teacher.

Table 12: Teacher pay equations
Dependent variable Log of Monthly Pay (Rupees)

	UP			Bihar		
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	OLS	School FE	OLS	OLS	School FE
Male	0.0528	0.0574	0.0528	0.0603**	0.0613**	0.0531**
	(1.31)	(1.35)	(1.31)	(2.36)	(2.37)	(2.10)
Age	0.00998***	0.00994***	0.00998***	0.0195***	0.0195***	0.0196***
	(3.92)	(3.69)	(3.92)	(12.43)	(12.30)	(12.78)
BA	0.0646	0.0696	0.0646	-0.0258	-0.0257	-0.0314
	(1.35)	(1.38)	(1.35)	(-0.95)	(-0.94)	(-1.19)
MA	0.0149	0.0179	0.0149	0.0535	0.0524	0.0538
	(0.26)	(0.29)	(0.26)	(1.53)	(1.49)	(1.54)
First division	0.0192	0.0302	0.0192	0.00674	0.00869	0.00355
	(0.53)	(0.79)	(0.53)	(0.32)	(0.41)	(0.17)
Teacher training	0.0701	0.0738	0.0701	0.0914***	0.0935***	0.0860***
	(1.34)	(1.35)	(1.34)	(3.22)	(3.21)	(2.93)
Contract teacher	-1.117***	-1.108***	-1.117***	-0.575***	-0.572***	-0.579***
	(-17.42)	(-16.53)	(-17.42)	(-17.27)	(-17.05)	(-17.86)
Average school achievement (mean z-score)		-0.0401			-0.00945	
		(-0.58)			(-0.27)	
Constant	8.712***	8.662***	8.712***	8.225***	8.220***	8.231***
	(51.42)	(47.70)	(51.42)	(87.48)	(86.62)	(89.05)
N	208	198	208	392	389	392
No. of schools			63			71
R^2	0.851	0.845		0.826	0.826	
Ceteris paribus Salary Ratio (Regular/Contract)			3.06			1.78
Ceteris paribus Salary Gap (Regular – Contract)			4087			1605

Appendix 1: Descriptive statistics of key variables

	UP		Bihar	
Variable	Mean	SD	Mean	SD
Child characteristics				
Math Score	31.05	43.20	62.40	58.16
Reading Score	32.71	37.39	69.36	49.39
Male	0.50	0.50	0.54	0.50
Age in years	8.79	1.70	9.09	1.63
Weight (log)	9.26	2.51	9.50	2.26
Height (cm)	121.94	10.66	127.08	10.60
Illness*	0.41	0.49	0.48	0.50
Father's education (years)	3.48	4.38	4.41	4.80
Mother's education (years)	0.91	2.41	1.68	3.30
Asset index (log) [1]	1.20	0.97	1.11	0.99
Takes private tuition	0.04	0.20	0.40	0.49
Teacher characteristics				
Age	32.50	11.18	32.30	9.38
Male	0.51	0.50	0.59	0.49
BA qualification	0.38	0.49	0.31	0.46
MA qualification	0.22	0.41	0.12	0.33
First division	0.17	0.38	0.47	0.50
Contract teacher	0.71	0.46	0.73	0.44
Absence rate	0.12	0.18	0.20	0.20
School characteristics				
School resources index[2]	6.85	1.31	4.82	1.24
Pupil Teacher ratio[3]	35.38	16.35	34.30	13.13
Textbook ratio[4]	0.79	0.23	0.63	0.23
Always get a mid-day meal	0.81	0.39	0.04	0.19

Note: * Was ill enough to take 4 or more consecutive days off school in past 3 months. Note these are means of variables taken from the merged child, teacher, school dataset. Thus, teacher and school characteristics are effectively weighted by the number of grade 2 and 4 students in each school. Thus, the teacher absence rate is lower here than would appear to be the case in Table 1, because the schools with more children (present) in grades 2 and 4 have lower teacher absence rates, and they get a higher weight when taking the averages.

[1]The asset index is a composite index of the following items with following weightings: Charpai, bed, wallclock, chair and table – enter directly; fan, bicycle, cd player and radio – multiply by 2; B&W TV, gas stove, cooker, mobile and telephone- multiply by 3; colour tv, fridge or motorbike- multiply by 5.

[2] The school resource index incorporates information on not only the availability of resources, but whether or not they are in working order. It includes the following items; table for the teacher, existence of a fan, ability to open windows, blackboard that can be written on with chalk, mat or jute for children to sit on, desk for the majority of children, a library, a working tape-recorder, working electricity, a boundary wall, drinkable water and a working toilet.

[3] The pupil-teacher ratio was calculated taking into account the fluidity of class-room arrangements in the schools. It explicitly accounts for multi-grade teaching, and is measured by the total-number of pupils within the class, irrespective of grade.

[4] The textbook ratio is the number of children with a textbook for each subject, divided by the number of pupils in the class.

Appendix 2

Saturated Model

For the saturated model we adapt Derecho and Glewwe (2002). We take a production function of the form,

$$T_{ijs} = h_s(\mathbf{SC}_j, TC_{k,} \mathbf{FC}_i) + \varepsilon_{ijs} \quad (1)$$

Where T_{ijks} denotes the test score of child i, in school j, with teacher k in subject s;

And $\mathbf{SC}_j$ denotes the vector of school characteristics;

And TC_k denotes the vector of teacher characteristics;

And $\mathbf{FC}_i$ denotes the vector of child and household characteristics.

ε_{ijks} is defined to incorporate random noise that is uncorrelated with SC, TC and FC.

and estimate a linear approximation of (1) using a Taylor Approximation;

$$T_{ijk} = \beta_0 + \boldsymbol{\beta}_1'\mathbf{SC}_j + \boldsymbol{\beta}_2'\mathbf{TC}_k + \boldsymbol{\beta}_3'\mathbf{FC}_i + \boldsymbol{\beta}_4'\mathbf{SC}_j \otimes \mathbf{TC}_k + \boldsymbol{\beta}_5'\mathbf{SC}_j \otimes \mathbf{FC}_i + \boldsymbol{\beta}_6'\mathbf{TC}_k \otimes \mathbf{FC}_i + \boldsymbol{\beta}_7'\mathbf{SC}_j \otimes \mathbf{TC}_k \otimes \mathbf{FC}_i + \varepsilon_{ijk} \quad (2)$$

Where $\mathbf{SC}_j \otimes \mathbf{TC}_k$ denotes the interaction between school and teacher characteristics and so on and so forth.

We wish to know the effect on test scores of being taught by a contract teacher as opposed to a regular teacher. Defining a typical contract teacher as a weighted average of all the characteristics of contract teachers, where the weights are the proportion of children taught by that teacher:

$$\overline{TC}_p = \sum_{j \in P} w_{jp}\mathbf{TC}_k \quad (3)$$

here P is the set of all contract teachers and w_{jp} is the fraction of total children taught by contract teachers. Similarly the vector of characteristics for the typical regular teacher can be defined as:

$$\overline{TC}_r = \sum_{j \in R} w_{jr}\mathbf{TC}_k \quad (4)$$

Inserting (3) into (2) we can derive the expected test score of child i if he/she is taught by a contract teacher

$$E[T_i|\ \mathbf{TC}_k, \text{contract teacher}] = \beta_0 + \boldsymbol{\beta}_1'\mathbf{SC}_j + \boldsymbol{\beta}_2'\overline{TC}_p + \boldsymbol{\beta}_3'\mathbf{FC}_i + \boldsymbol{\beta}_4'\mathbf{SC}_j \otimes \overline{TC}_p + \boldsymbol{\beta}_5'\mathbf{SC}_j \otimes \mathbf{FC}_i + \boldsymbol{\beta}_6'\overline{TC}_p \otimes \mathbf{FC}_i + \boldsymbol{\beta}_7'\mathrm{SC}_j \otimes \overline{TC}_p \otimes \mathbf{FC}_i \quad (5)$$

And inserting (4) into (2) we can derive the expected test score of child i if he/she is taught by a regular teacher.

$$E[T_i|\ \mathbf{TC}_k, \text{regular-teacher}] = \beta_0 + \boldsymbol{\beta}_1'\mathbf{SC}_j + \boldsymbol{\beta}_2'\overline{TC}_r + \boldsymbol{\beta}_3'\mathbf{FC}_i + \boldsymbol{\beta}_4'\mathbf{SC}_j \otimes \overline{TC}_r + \boldsymbol{\beta}_5'\mathbf{SC}_j \otimes \mathbf{FC}_i + \boldsymbol{\beta}_6'\overline{TC}_r \otimes \mathbf{FC}_i + \boldsymbol{\beta}_7'\mathrm{SC}_j \otimes \overline{TC}_r \otimes \mathbf{FC}_i \quad (6)$$

If we then normalize all SC, TC and FC variables to have means equal to zero, then we are left with

$\beta_0 + \boldsymbol{\beta}_2'\overline{TC}_p$ = expected test score of *average* child with average contract teacher in average school

$\beta_0 + \boldsymbol{\beta}_2'\overline{TC}_r$ = expected test score of *average* child with average regular teacher in average school

We are interested in the expected change in test scores by switching from having a regular teacher to a contract teacher. That is

$$\boldsymbol{\beta}_2'(\mathbf{TC}_p - \mathbf{TC}_r) \quad (7)$$

Which we can estimate through regression analysis using a conventional dummy variable, $D_c = 1$ if a child is taught by a contract teacher, and $D_c = 0$ if the child is taught by a regular teacher. If children are assigned to contract teachers randomly, then we can simply estimate an OLS regression with this dummy variable and we would have an estimate of the contract teacher effect. Unfortunately we know that this isn't the case, and that contract teachers are non-randomly assigned to schools. We can overcome this problem by estimating the model using school-fixed effects, whereby identification of D_c comes from within-school variation in teacher types – that is variations in test scores within a school dependent on teacher type. This reduces our model to

$$T_{ik} = \beta_0 + \beta_1 TC_k + \beta_2 FC_i + \beta_3 TC_k FC_i + \varepsilon_{ij} \quad (8)$$

Which we can estimate using the dummy variable D_c in the following equation

$$T_{ij} = (\beta_0 + \beta_1\overline{TC}_r) + \beta_1(\overline{TC}_p - \overline{TC}_r)D_c + (\beta_2 + \beta_3\overline{TC}_r)FC_i + \beta_3(\overline{TC}_p - \overline{TC}_r)D_cFC_i + \varepsilon_{ij}$$

(9)

Appendix 3: Achievement Production Function with controls for teacher training

	UP		Bihar	
	OLS	School FE	OLS	School FE
Grade 4	0.404***	0.538***	0.910***	1.031***
	(4.29)	(16.49)	(15.22)	(37.46)
Hindi	0.0505*	0.0657***	0.176***	0.201***
	(1.98)	(3.64)	(6.32)	(10.10)
Survey Number	0.325***	0.327***	0.277***	0.287***
	(9.19)	(17.50)	(12.36)	(14.60)
Child characteristics				
Age in years	0.0398**	0.0713***	0.0334**	0.0210**
	(2.16)	(8.58)	(2.41)	(2.47)
Male	0.153***	0.144***	0.264***	0.256***
	(3.74)	(7.61)	(7.10)	(12.99)
Height(cm)	0.0161***	0.0127***	0.00335*	0.00102
	(6.65)	(10.43)	(1.75)	(0.82)
Illness	-0.0943***	-0.0911***	-0.0778***	-0.0552***
	(-3.05)	(-4.81)	(-2.91)	(-2.83)
Father's education	0.0262***	0.0211***	0.00964*	0.0132***
	(5.12)	(8.29)	(1.77)	(4.84)
Mother's education	0.0270***	0.0278***	0.0274***	0.0239***
	(3.33)	(6.73)	(3.67)	(6.76)
Asset index (ln)	0.0465**	0.0329***	0.0769***	0.0622***
	(2.01)	(2.70)	(3.35)	(4.88)
Takes tuition	0.255***	0.270***	0.270***	0.191***
	(3.23)	(5.69)	(6.69)	(8.73)
Teacher characteristics				
Age	0.0116***	0.0139***	0.00139	0.00642***
	(2.88)	(6.89)	(0.50)	(3.46)
Male	-0.0293	-0.153***	0.0344	-0.0519*
	(-0.48)	(-5.28)	(0.69)	(-1.76)
BA	0.0203	0.0879**	0.00123	-0.00890
	(0.28)	(2.35)	(0.02)	(-0.30)
MA	-0.0353	0.125***	0.0639	0.0653
	(-0.48)	(3.25)	(0.91)	(1.45)
First division	0.0733	0.123***	-0.0187	0.00665
	(0.78)	(3.09)	(-0.48)	(0.26)
Contract teacher	0.0923	0.161***	-0.0448	0.0660*
	(0.76)	(3.27)	(-0.83)	(1.85)
Teacher training	-0.0357	-0.212***	-0.174***	-0.120***
	(-0.53)	(-5.20)	(-4.23)	(-3.47)
School characteristics				
Textbook ratio	0.440***		0.118	
	(3.76)		(0.91)	
Resource index	0.0991***		0.0325*	
	(2.95)		(1.71)	
Meal always	0.103		-0.105	
	(1.47)		(-0.96)	
Pupil-teacher ratio	0.000678		0.000805	
	(0.47)		(0.70)	
Pupils	2330	2330	2003	2003
N	8165	8185	6678	6774
No. of schools		62		71
R^2	0.290	0.282	0.366	0.363