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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 fixed effects and value-added models of the education production function, using Indian data. We allow for both homogenous and heterogeneous treatment effects, to highlight the mechanisms through which the contract teacher effect works. We also present school fixed effects teacher pay equations and predict achievement marks per Rupee spent on 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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The relative effectiveness and costs of contract and regular teachers in India

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

[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).

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 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 (Hanushek, 2003). 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

[2] Govinda and Josephine (2004), Kumar, *et al* (2001)
[3] Drèze and Sen (2002), Leclercq (2002)

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 OLS 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, in an OLS equation, the contract teacher dummy variable is likely 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*, i.e. when the potentially non-random matching of contract teachers to particular schools on the basis of their unobserved characteristics is taken account of. 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 their paper, the contract teacher effect appears to be indistinguishable from the effect of the

[4] Based on our analysis of Indian National Sample Survey (2004-05).

reduction in class size that accompanies the provision of an extra contract teacher[5]. A randomized trial that has the power to estimate the pure 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 fixed effects models and value added models, and it permits us to control for class-size, multi-grade teaching and pedagogical style, which allow us to get closer to the causal contract teacher effect. In addition, the use of a saturated model of the achievement production function, allows us to look at how the contract teacher effect works by allowing heterogeneity of treatment. Section 2 sets out the methodology and data used. Section 3 presents the results and the last section concludes.

[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.

1 Data and methodology

1.1 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 rich source of data with detailed questions on the children's personal traits (age, gender, height, illness); family background (caste, religion, 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.

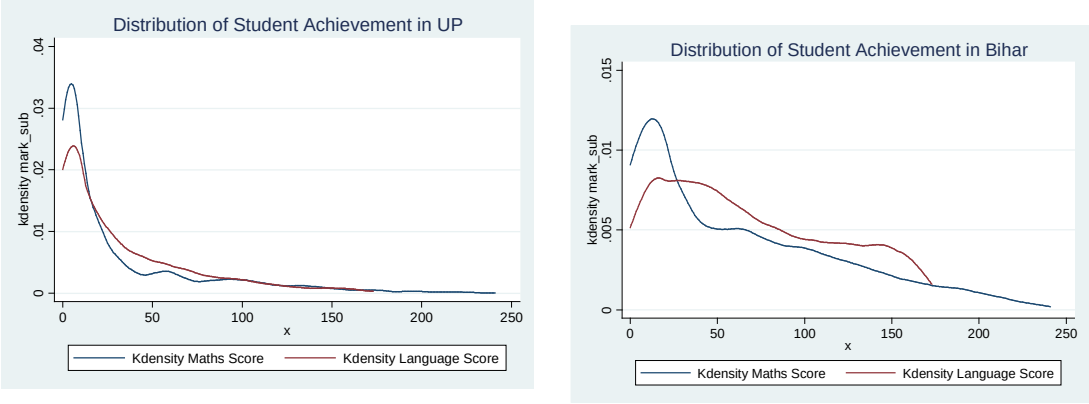

Figure 1: Distribution of student achievement

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 less skewed. 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.

1.2 Differences between regular and contract teachers

Before examining the main question, we present some descriptive statistics (Table 1) to highlight key differences between teacher types, and contractual differences across states. In UP contract teacher jobs are annually renewable while in Bihar they are jobs for life, leading to Bihar teachers facing weaker accountability pressures than UP contract teachers.

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).

1.3 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 data on 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 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 observed and unobserved school-level characteristics, which do not vary within schools.

Even after controlling for all observed and unobserved school characteristics, our estimate of the contract teacher effect may be biased due to the potential non-random matching of teachers to pupils within a school. This is possible across grades, but not within grades (as each school only has one class per grade). If this is the case, teachers of certain type may match to children of higher ability, e.g. by teaching the grade they perceive as having the more able children. To address this possibility, and as each child was tested twice in our sample (at the start and end of the school year), we estimate a value-added School Fixed Effects 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:

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

Where $(A_{ijkl,t+1} - A_{ijkl,t})$ denotes changes in the achievement level of the i^{th} student in the j^{th} school with the k^{th} teacher between time t and t+1, that is the start and the end of the school year.

After estimating the causal impact of contract teachers we try to explain our findings, using two different approaches. Firstly, we look at the impact that contract teachers have on reducing class-size and alleviating multi-grade teaching, and ask if the contract teacher effect is really a class-size effect. Secondly we use measures of teacher effort to investigate the proposition that renewable contracts induce higher levels of teacher effort.

A notable drawback of these models is that we identify the average treatment effect (ATE) under the assumption of homogeneity of treatment. While it is possible that the impact of

contract teachers on achievement is constant over pupil types and across different school scenarios, one can also imagine situations where contract teachers will work well in certain scenarios, and less in others. As such, the contract teacher effect is likely to be heterogeneous across scenarios, and this variation is unlikely to be uncorrelated with anything of interest. As Deaton (2010) points out, it is exactly this variation which will illuminate our enquiry. So finally we allow for heterogeneous treatment effects across observable characteristics by 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 control for all heterogeneous treatment effects and can estimate the Average Treatment Effect (ATE) of being taught by a contract teacher after controlling for all possible heterogeneity of treatment. 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. However, the ATE may not be particularly applicable in this context given the non-randomised nature of contract teacher appointments and differences in characteristics by teacher type. We are not interested in the average teacher, rather the effect of contract teachers given the interactions between teacher characteristics and contractual status. In a true randomised trial this information is embodied in the treatment effect, so to accurately compare our findings we cannot purely focus on an ATE that is independent of these interactions. By allowing for heterogeneous treatment effects this method allows us to see the pathways through which the contract teacher effect works and identify the differences in characteristics which influence the

results. It is the findings regarding the heterogeneity of treatment, rather than the ATE itself, which offers the most valuable information with regards how contract teachers impact on learning and the likely effects of future contract teacher appointments. A full derivation of the model can be found in Appendix 2.

We are estimating the achievement equations on a sample of children enrolled in government schools only and, in principle, this could be a selected sample (both due to selectivity into enrolment and into government schools). Using the Heckman approach, selection into government school was modelled using the existence of a private school in the village as the identifying exclusion restriction. We found weak negative selection into government schools but our estimated contract teacher effects were not significantly affected by selectivity bias.

Given the dominance of low scores in our data-set, and the skewness of the test-score distribution, our estimations are likely to suffer from 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[6]. We use clustering at the school level in our OLS equations to address heteroskedastcitiy. We also try an alternative functional form of the dependent variable (namely the log of test scores), which are more normally distributed, and the results were largely unaffected.

2 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.

[6] An alternative would be to estimate a non-linear model, such as a count model; however we then lose the ability to use the school fixed effects estimator since 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.

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 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. 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[7] has strong effects, with children who receive external tutoring 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.[8]

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. The increase in the coefficient on the contract teacher variable when moving 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

[7] Private tuition is privately tutored paid lessons taken outside of school, usually in the evenings. They are a fee-paying service conducted by independent tutors (i.e. not their school teacher).

[8] 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.

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)[9]. In other words, in across-school estimation, the contract teacher variable is partly 'picking up' the effect of community's deprivation.

After controlling for observed teacher characteristics and for all observed and unobserved school characteristics (column 4), contract teachers raise child test scores by about 0.21 SD compared to being taught by a regular teacher[10]. Here our identification comes from two sources: differences in teacher type across grades (2 and 4) and across subjects (maths and language, within the same grade). Table 3 shows the exact breakdown of the contract teacher effect by its constituent parts. Columns (2) and (3) estimate the contract teacher effect from within-subject/across-grade differences in teacher type, where a contract teacher teaches the subject to grade 2 while the regular teacher teaches the same subject to grade 4 (or vice-versa). Column (4) identifies effects from across subject/within grade differences in teacher type, where pupils are taught by a regular teacher for one subject and a contract teacher for the other. We report this for grade 4 only, as there is insufficient variation in teacher-type across subject in grade 2 to draw meaningful conclusions. Unfortunately this lack of variation means that in a pupil-fixed effects equation (estimated but not shown) the contract teacher effect could not be identified.

The estimated effect in column (1) is a weighted average of columns (2)-(4), with the majority of the variation being across grades[11]. Estimating the model using only across-grade

[9] 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.
[10] This result is robust to changes in functional form (not shown). The contract teacher effect using the z-score of log of subject marks produces a significant contract teacher effect of 0.24 SD.
[11] Results from grade 2 only are excluded as only 4% of pupils are taught by a contract teacher in one subject and a regular teacher in another. In contrast, approximately 65% of schools have within-subject across grade variation in teacher type.

variation yields estimates of a contract teacher effect of 0.289 SD for reading scores and 0.163 SD for maths scores, while using only across subject variation within grade 4 (last column) shows a slight positive, but insignificant contract teacher effect. However, identification here comes from a small percentage of children (12%) who are taught by contract teachers in one subject and regular teachers in the other.

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.[12] The differential between maths and language scores is also greater in Bihar, 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 are significantly related to cognitive outcomes, as are household wealth, parental education and taking private tuition. Teacher characteristics other than age and gender are insignificantly correlated with student achievement.

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), possibly due to contract teachers facing lower

[12] 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)). A potential explanation this is that Bihar students are much more likely to take private tuition (40% of the sample compared to 4% in UP). 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.

accountability pressures Bihar, where they have jobs for life (as opposed to annually renewable contracts in UP).

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[13]. We now turn to the question of why this is the case and ask whether our estimated para teacher effect could be biased due to non-random matching of teachers to pupils within schools.

3 Why are contract teachers more effective than regular teachers?

We investigate three possible reasons why contract teachers may be more effective than regular teachers: (a) that our results are spurious, being biased due to non-random matching of teachers to pupils within schools; (b) that the appointment of contract teachers may lead to lower class sizes and/or reduced incidence of multi-grade teaching, so that it in fact represents a class-size effect; and (c) that contract teachers may exhibit more effort or differing classroom styles due to the insecure nature of their contracts and their consequent higher accountability than regular teachers.

3.1 Non-random matching of teachers to more able pupils within schools

Even in within-school estimation, the contract teacher variable is potentially endogenous if there is non-random matching of teachers to pupils. Non-random matching within each grade is not possible in this sample (and in the majority of government of India primary schools) as each grade has only one class, and indeed many schools have fewer teachers than classes, leading to multi-grade teaching. So it is not possible for a regular (or contract teacher) to select

[13] In addition, 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). We can consider those appointed in 2006 and with training as a separate group to those who were appointed either pre-2006 or in 2006 without training. Re-estimating the model (shown in appendix 4) we find statistically no difference in the relative effectiveness of contract teachers with and without pre-service training.

which class they wish to teach within each grade. It is however possible that there is non-random matching of teachers to grades. If this is the case, and there are differences in pupils' ability across grades, then it may be possible that our school fixed effects estimates are biased. Given the high attrition of students in India (the drop-out rates at the end of grades 2 & 3 in UP are 10 and 12.7% respectively[14]) and the fact that more able students are likely to continue in schools, the average grade 4 pupil is likely to be more innately able than the average pupil in grade 2. This could bias our estimates if teachers can select which grades they teach. In UP however, there is a stipulation that contract teachers teach grades 1 and 2, while regular teachers teach grades 3, 4 and 5, which suggests that our estimated contract teacher effect is, if anything, biased downwards since contract teachers in fact teach grade 2 children who are likely to be less able, on average, than the grade 4 children that are supposed to be taught by regular teachers. Even if this stipulation was ignored and teachers could match to particular grades, the greater status of regular teachers makes it highly unlikely that contract teachers would be able to match to the more able grade/pupils. Nevertheless, to address the worry that contract teachers may still somehow be matched with abler students even within a school, we re-estimate the model as a school fixed effects value-added model of achievement, 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. A value-added model greatly reduces the endogeneity problem without necessarily eliminating it.[15] Before presenting the results of the value-added model, we first discuss class-size as a factor that potentially confounds the contract teacher effect.

[14] DISE State Report Card (2007/2008)

[15] Since children with higher initial ability not only have higher levels of achievement, but may also have greater changes in achievement over time.

3.2 Changes in class-size and multi-grade teaching

In addition to non-random matching of teachers to more able students, it is possible that they are also matching to classes which are perceived to be easier to teach, such as smaller classes and mono-grade classes. As with ability bias, this type of non-random matching is likely if anything to lead to an underestimation of the contract teacher effect, since regular teachers (being longer-serving, permanent and far better-paid employees) are the more likely to match to the smaller and to the mono-grade classes.

However, there may be reason to worry that the contract teacher 'effect' is in fact a class-size effect. The provision of contract teachers may have beneficial effects on child learning 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 6 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 difference 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 6 shows that in Bihar, number of contract teachers in a school is significantly negatively correlated with the incidence of multi-grade teaching. It also 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. However, the correlation of the 'number of contract teachers appointed to a school' with

official pupil-teacher ratio is higher than its correlation with the actual pupil-teacher ratio in both states. This suggests that the appointment of extra contract teachers does not lead to a corresponding reduction in actual pupil-teacher ratios, presumably as it leads to higher teacher absence rates. This is similar to the findings for Kenya in Duflo, Dupas and Kremer (2009), where the appointment of contract teachers led to an increase in the absence of regular teachers.

Is it the case then that the estimated contract teacher effect is really an effect of reduced class-size and improved classroom organisation? This would lead to an over-estimate of the contract teacher effect. In contrast, if regular teachers are matching to smaller or mono-grade classes then this will bias our estimates downwards.

Table 7 shows the results of a model which controls for both: possible bias due to matching to more able pupils, and the influence of class-size and mono-grade teaching. Columns (1) to (3) use school fixed effects and include controls 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. Columns (4) – (6) estimate the value-added school fixed effects model, using the z-score of 'change in achievement over the school year'. The class-size (pupil-teacher ratio, PTR) effect is weakly significant with a small coefficient in the fixed effects estimation (columns 2) in both states. Mono-grade teaching has a large positive association with achievement in UP (column 3), 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.

When we estimate a school fixed effects model of value-added in achievement in the last three columns of Table 7, we find contract teachers to have a positive significant effect on *changes* in achievement over the school year, of a very similar magnitude to the non-value added specification. This is true in both states, but the decrease in precision of the estimates means the effect is insignificant in Bihar. While it does not eliminate bias, a value-added model greatly reduces it. The results suggest that endogenous matching of contract teachers to more able pupils is unlikely to be driving the the positive contract teacher effect.

3.3 Changes in teacher effort

An additional possible explanation of the contract teacher effect 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 higher effort, via lower (about half) absence rates than regular teachers. In Table 8 we re-estimate the school-fixed effect achievement equation (from 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 8 shows that the contract teacher effect is very robust to inclusion of controls for teacher effort. Statistically there is no difference among the point estimates 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 8. 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 8. 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)[16]. This is consistent with Bourdon et al.'s (2007) finding that contract teachers are particularly effective when teaching lower ability pupils. 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[17]. One potential explanation of the contract teacher effect is as follows: the lower salaries of contract teachers may imply that only persons

[16] Our conclusions are hindered by the fact this is self-reported data, but it is unclear why contract teachers should be more likely to report this than regular teachers.

[17] Glewwe, Ilias and Kremer (2010) find that a teacher performance pay program in Kenya did not increase teacher effort in many obvious dimensions. For instance, teachers in program schools were not more likely to be in school, or assign homework or adopt different pedagogical practices, but they increased their test preparation sessions.

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.

4 Heterogeneous treatment effects of contract teachers

The previous models have shown that the contract teacher effect is both positive and robust. 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 due to the treatment effect being heterogeneous across observable characteristics of teachers and pupils. 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) after allowing treatment to differ by observed characteristics. 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 given different observed characteristics of pupils and teachers. A significant coefficient on the interaction between contract teacher variable and a given child characteristic indicates that the contract teacher effect differs by child characteristic. Similarly a significant

coefficient on the interaction between the contract teacher variable and any given teacher characteristic indicates that the contract teacher effect differs by the characteristics of the teachers in the school. Thus, the interaction terms allow us to identify the scenarios where contract teachers are likely to have a positive effect.

In both UP and Bihar the ATE of the contract teacher variable is small and statistically insignificant. However our true treatment effect is the ATE plus the heterogeneous effects of contract teachers by observable child and teacher characteristics. A F-test of insignificance of all the interaction terms is decisively rejected in both states; interactions between contract teachers and our observable characteristics have a significant effect on learning outcomes. This shows that the contract teacher effect is heterogeneous with regards pupils and teacher characteristics.

In both states male contract teachers are more effective than male regular teachers. Evaluating the effect at the mean ratio of male to female teachers, 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. This shows that the average treatment effect of having a contract teacher depends on the gender of the contract teacher.

In UP, contract teachers have heterogeneous effects across children of differing health status, both in terms of child height and short term illness. Children with below average height and fathers with below average levels of education have positive treatment effects from having a contract teacher in UP. This may suggest that contract teachers reduce the negative impact of coming from families with lower SES. In Bihar, we find differential treatment effects of contract

teachers with relation to children taking 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 there is substantial heterogeneity in the effects of contract teachers across pupil and teacher types. Most notably, the contract teacher effect is dependent on the gender of the contract teacher and the socio-economic status of pupils. This suggests that while the average pupil in the average school will neither benefit nor suffer from being taught by a contract teacher, he/she will gain if he/she is of below average socio-economic status and if the contract teacher is male.

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. Our estimations predict that the average student taught by a regular teacher would score 25.5 marks in UP (63.4 marks in Bihar), while the average student taught by a contract teacher would score 33.9 marks in UP (67.1 marks in Bihar). Thus being taught by a contract teacher leads to a 33% increase in marks in UP and a 6% increase in marks in Bihar, compared to being taught by a regular teacher.

To illustrate this point, Table 10 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). This cost disadvantage of regular teachers holds over the entire range of the 95% confidence interval of our estimates, with the regular : contract ratio of costs per achievement point ranging from 4.93 - 5.70 in UP, and from 2.73 – 2.88 in Bihar

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 11 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%[18]. This translates to regular teachers earning 3.06 times more than (otherwise comparable) contract teachers in UP, and 1.78 times more in Bihar.

[18] 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 teachers 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. A plausible reason why contract teachers apply greater effort than regular teachers is due to the insecure annually-renewable nature of their contracts, i.e. the strong accountability pressure they face. 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 into account suggests that they apply greater effort in dimensions other than being present in school and the other dimensions of effort captured here.

In Bihar, contract teachers do not face strong accountability[19], 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 three years after first appointment, creating some weak accountability pressures. While these pressures are clearly not strong enough to elicit a difference in contract teachers' school attendance habits, they may lead to an increase in effort-levels in dimensions that were not captured in our data.

One explanation of the positive contract teacher effect could be that persons who become contract teachers are of a different type than regular teachers; for example, the far 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 children being socially disadvantaged, possibly due to the lesser 'social distance' between contract teachers and their pupils, relative to the much more highly-paid 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.

[19] 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. As of Spring 2010, all Bihar contract teachers' jobs have been re-confirmed.

That contract teachers are less socially-distant from their students is supported by evidence in Kingdon (2010) which estimates that in 2005 the ratio of regular 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". Para teachers who are paid a quarter as much as regular teachers in UP are closer to their students, in terms of their socio-economic background.

The saturated model also suggests that the positive contract teacher effect is partly due the 'para' teacher contracts making *male* teachers noticeably more effective (likely a product of renewable contracts).

Apart from being more effective in imparting learning than regular teachers, contract teachers 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 teacher's wage in UP, and 56% of the regular 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***
	(0.0847)	(0.0932)	(0.0310)	(0.0327)
Hindi	0.0449*	0.0512*	0.0587***	0.0658***
	(0.0243)	(0.0256)	(0.0179)	(0.0181)
Survey Number	0.309***	0.323***	0.324***	0.325***
	(0.0374)	(0.0354)	(0.0188)	(0.0187)
Child Characteristics				
Age in years	0.0307	0.0390**	0.0650***	0.0683***
	(0.0189)	(0.0176)	(0.00830)	(0.00831)
Male	0.134***	0.155***	0.157***	0.147***
	(0.0459)	(0.0407)	(0.0189)	(0.0189)
Height (cm)	0.0168***	0.0162***	0.0131***	0.0132***
	(0.00263)	(0.00241)	(0.00122)	(0.00121)
Illness	-0.0666*	-0.0958***	-0.0882***	-0.0922***
	(0.0350)	(0.0299)	(0.0190)	(0.0190)
Father's education	0.0245***	0.0259***	0.0215***	0.0210***
	(0.00531)	(0.00511)	(0.00255)	(0.00255)
Mother's education	0.0255***	0.0271***	0.0284***	0.0281***
	(0.00812)	(0.00812)	(0.00414)	(0.00413)
Asset index (ln)	0.0726***	0.0464*	0.0296**	0.0319***
	(0.0231)	(0.0233)	(0.0122)	(0.0122)
Takes tuition	0.229**	0.257***	0.269***	0.270***
	(0.0919)	(0.0788)	(0.0476)	(0.0475)
Teacher characteristics				
Contract teacher	-0.105	0.105	-0.00609	0.208***
	(0.0970)	(0.120)	(0.0315)	(0.0486)
Age		0.0111***		0.0107***
		(0.00393)		(0.00193)
Male		-0.0251		-0.131***
		(0.0623)		(0.0286)
BA		0.0198		0.0996***
		(0.0737)		(0.0374)
MA		-0.0388		0.0960**
		(0.0754)		(0.0382)
First Division		0.0738		0.153***
		(0.0949)		(0.0396)
School characteristics				
Textbook ratio		0.425***		
		(0.116)		
Resource index		0.0995***		
		(0.0336)		
Meal always		0.0975		
		(0.0694)		
Pupil-teacher ratio		0.000582		
		(0.00140)		
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 Fixed Effects, by subject and by grade

	School FE			
	(1)	(2)	(3)	(4)
		Both grades (2 and 4)		Grade 4 Only
	Both Subjects	Maths only	Reading only	Both Subjects
Grade 4	0.536***	0.546***	0.547***	
	(0.0327)	(0.0551)	(0.0414)	
Hindi	0.0658***			0.0450
	(0.0181)			(0.0351)
Survey number	0.325***	0.312***	0.338***	0.399***
	(0.0187)	(0.0286)	(0.0238)	(0.0345)
Child characteristics				
Age in years	0.0683***	0.0611***	0.0743***	0.0891***
	(0.00831)	(0.0128)	(0.0105)	(0.0157)
Male	0.147***	0.0748***	0.225***	0.171***
	(0.0189)	(0.0289)	(0.0241)	(0.0359)
Height (cm)	0.0132***	0.0120***	0.0142***	0.0162***
	(0.00121)	(0.00186)	(0.00155)	(0.00228)
Illness	-0.0922***	-0.101***	-0.0846***	-0.150***
	(0.0190)	(0.0291)	(0.0242)	(0.0352)
Father's education	0.0210***	0.0242***	0.0182***	0.0307***
	(0.00255)	(0.00391)	(0.00324)	(0.00449)
Mother's education	0.0281***	0.0294***	0.0273***	0.0427***
	(0.00413)	(0.00635)	(0.00524)	(0.00711)
Asset index (ln)	0.0319***	0.0338*	0.0289*	0.0265
	(0.0122)	(0.0187)	(0.0155)	(0.0227)
Takes tuition	0.270***	0.306***	0.231***	0.325***
	(0.0475)	(0.0733)	(0.0600)	(0.0803)
Teacher Characteristics				
Contract teacher	0.208***	0.163**	0.289***	0.0937
	(0.0486)	(0.0806)	(0.0633)	(0.321)
Age	0.0107***	0.0119***	0.00886***	0.00845
	(0.00193)	(0.00311)	(0.00259)	(0.0141)
Male	-0.131***	-0.155***	-0.117***	-0.120
	(0.0286)	(0.0463)	(0.0421)	(0.148)
BA	0.0996***	0.0942	0.0811	0.169
	(0.0374)	(0.0611)	(0.0527)	(0.208)
MA	0.0960**	0.0754	0.132**	0.194
	(0.0382)	(0.0630)	(0.0519)	(0.303)
First Division	0.153***	0.151**	0.154***	-0.141
	(0.0396)	(0.0615)	(0.0593)	(0.161)
N	8185	4129	4056	3733
No. of schools	62	62	61	61
R^2	0.280	0.252	0.327	0.0316

Notes: Model also includes dummies for missing observations in parental education, private tuition and child health. Constant included but not shown. SE 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***
	(0.0554)	(0.0617)	(0.0262)	(0.0275)
Hindi	0.184***	0.176***	0.187***	0.200***
	(0.0240)	(0.0259)	(0.0192)	(0.0200)
Survey Number	0.281***	0.276***	0.288***	0.287***
	(0.0224)	(0.0224)	(0.0197)	(0.0197)
Child characteristics				
Age in years	0.0352**	0.0358**	0.0218**	0.0219**
	(0.0141)	(0.0137)	(0.00852)	(0.00853)
Male	0.269***	0.269***	0.258***	0.257***
	(0.0365)	(0.0374)	(0.0197)	(0.0198)
Height (cm)	0.00348*	0.00312	0.000943	0.000962
	(0.00193)	(0.00195)	(0.00125)	(0.00125)
Illness	-0.0646**	-0.0731***	-0.0560***	-0.0558***
	(0.0291)	(0.0275)	(0.0195)	(0.0195)
Father's education	0.00873	0.00939*	0.0133***	0.0134***
	(0.00536)	(0.00543)	(0.00272)	(0.00272)
Mother's education	0.0266***	0.0268***	0.0239***	0.0237***
	(0.00752)	(0.00752)	(0.00354)	(0.00354)
Asset index (ln)	0.0798***	0.0778***	0.0637***	0.0629***
	(0.0244)	(0.0234)	(0.0127)	(0.0128)
Takes tuition	0.284***	0.279***	0.187***	0.190***
	(0.0419)	(0.0407)	(0.0219)	(0.0219)
Teacher characteristics				
Contract teacher	-0.00404	-0.0293	0.0322	0.0688*
	(0.0470)	(0.0548)	(0.0294)	(0.0358)
Age		-0.00229		0.00357**
		(0.00264)		(0.00166)
Male		0.0311		-0.0619**
		(0.0525)		(0.0294)
BA		-0.0338		-0.0280
		(0.0500)		(0.0294)
MA		-0.000797		0.0343
		(0.0693)		(0.0441)
First Division		0.00670		0.0197
		(0.0384)		(0.0255)
School characteristics				
Textbook ratio		0.0837		
		(0.142)		
Resource index		0.0280		
		(0.0192)		
Meal always		-0.0869		
		(0.117)		
Pupil-teacher ratio		0.00131		
		(0.00125)		
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: Achievement Production Function Bihar – School Fixed Effects, by subject and by grade

	School FE				
	(1)	(2)	(3)	(4)	(5)
		Both grades (2 and 4)		Grade 2 only	Grade 4 only
	Both Subjects	Maths only	Reading only	Both Subjects	Both Subjects
Grade 4	1.035***	1.144***	0.905***		
	(0.0275)	(0.0455)	(0.0380)		
Hindi	0.200***			0.266***	0.138***
	(0.0200)			(0.0231)	(0.0409)
Survey number	0.287***	0.289***	0.284***	0.326***	0.235***
	(0.0197)	(0.0302)	(0.0247)	(0.0218)	(0.0331)
Child characteristics					
Age in years	0.0219**	0.0146	0.0299***	0.0208**	0.00324
	(0.00853)	(0.0131)	(0.0108)	(0.00978)	(0.0146)
Male	0.257***	0.214***	0.300***	0.211***	0.326***
	(0.0198)	(0.0303)	(0.0250)	(0.0224)	(0.0342)
Height (cm)	0.000962	-0.00146	0.00367**	0.00484***	-0.00268
	(0.00125)	(0.00192)	(0.00157)	(0.00143)	(0.00214)
Illness	-0.0558***	-0.0573*	-0.0588**	-0.0303	-0.0867***
	(0.0195)	(0.0300)	(0.0246)	(0.0219)	(0.0331)
Father's education	0.0134***	0.0156***	0.0110***	0.0117***	0.0119**
	(0.00272)	(0.00417)	(0.00343)	(0.00310)	(0.00465)
Mother's education	0.0237***	0.0260***	0.0217***	0.0141***	0.0371***
	(0.00354)	(0.00544)	(0.00445)	(0.00405)	(0.00599)
Asset index (ln)	0.0629***	0.0656***	0.0604***	0.0565***	0.0569***
	(0.0128)	(0.0194)	(0.0163)	(0.0147)	(0.0219)
Takes tuition	0.190***	0.184***	0.201***	0.155***	0.232***
	(0.0219)	(0.0337)	(0.0276)	(0.0248)	(0.0373)
Teacher Characteristics					
Contract teacher	0.0688*	0.248***	0.0388	0.101*	0.00611
	(0.0358)	(0.0906)	(0.0668)	(0.0589)	(0.0673)
Age	0.00357**	0.00707*	0.00147	-0.00344	0.00464
	(0.00166)	(0.00367)	(0.00343)	(0.00270)	(0.00383)
Male	-0.0619**	-0.102*	0.00195	0.0367	-0.160**
	(0.0294)	(0.0525)	(0.0574)	(0.0445)	(0.0674)
BA	-0.0280	-0.0394	-0.0204	-0.0512	0.0828
	(0.0294)	(0.0550)	(0.0499)	(0.0517)	(0.0732)
MA	0.0343	0.0578	0.122**	0.0538	-0.134
	(0.0441)	(0.0998)	(0.0623)	(0.0854)	(0.0956)
First Division	0.0197	0.0204	0.00985	-0.0247	0.112**
	(0.0255)	(0.0556)	(0.0418)	(0.0360)	(0.0524)
N	6774	3465	3309	3595	3179
Number of groups	71	69	70	1038	1038
R^2	0.362	0.335	0.396	0.0832	0.0036

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

Table 6: 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 7: Achievement Production Function: School FE and Value-Added Model, controls for pupil-teacher ratio and multi-grade teaching

UP						
	School FE			School FE Value Added Model		
	(1)	(2)	(3)	(4)	(5)	(6)
Contract teacher	0.208***	0.203***	0.217***	0.208**	0.239***	0.204**
	(0.0486)	(0.0487)	(0.0486)	(0.0806)	(0.0813)	(0.0808)
Pupil-teacher ratio		0.00118*			-0.00871***	
		(0.000696)			(0.00242)	
Mono-grade class			0.373***			-0.0585
			(0.111)			(0.186)
Pupils	2330	2330	2330	2053	2053	2053
N	8185	8165	8185	3942	3942	3942
No. of schools				62	62	62
R^2	0.289	0.290	0.290	0.280	0.280	0.282
Bihar						
Contract teacher	0.0688*	0.0758**	0.0807**	0.0535	0.0576	0.0475
	(0.0358)	(0.0362)	(0.0359)	(0.0646)	(0.0651)	(0.0648)
Pupil-teacher ratio		0.00157**			0.00142	
		(0.000688)			(0.00188)	
Mono-grade class			-0.199***			0.0145
			(0.0506)			(0.0909)
Pupils	2003	2003	2003	1819	1819	1819
N	6774	6678	6774	3317	3317	3317
No. of schools				71	71	71
R^2	0.364	0.362	0.365	0.0200	0.0179	0.0193

Note: All equations control for teacher, child and home background characteristics but these are not shown. Constant included but not shown. *se* statistics in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 8: Achievement Production Function: School FE 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***
	(0.0486)		(0.0499)		(0.0505)		(0.0494)
Absence rate		-0.133*	-0.0595				
		(0.0777)	(0.0797)				
Time-on-task				0.0281	-0.0175		
				(0.0429)	(0.0440)		
Supports weak pupils						0.162***	0.143***
						(0.0485)	(0.0487)
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 9: 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	0.232***	0.237***	0.945***	0.121*
	(0.0727)	(0.0863)	(0.0588)	(1.80)
Hindi	-0.0310	0.115***	0.275***	-0.105**
	(0.0344)	(0.0407)	(0.0452)	(-2.02)
Survey Number	0.423***	-0.135***	0.274***	0.0166
	(0.0349)	(0.0412)	(0.0377)	(0.38)
Child characteristics				
Age in years	0.0683***	0.00872	0.0743***	-0.0695***
	(0.0144)	(0.0171)	(0.0168)	(0.0193)
Male	0.0815**	0.0932**	0.239***	0.0226
	(0.0349)	(0.0411)	(0.0381)	(0.0443)
Height (cm)	0.0183***	-0.00718***	-0.00415*	0.00687**
	(0.00209)	(0.00250)	(0.00248)	(0.00284)
Illness	-0.193***	0.134***	-0.0353	-0.0289
	(0.0350)	(0.0413)	(0.0373)	(0.0436)
Father's education	0.0307***	-0.0146***	0.0173***	-0.00518
	(0.00448)	(0.00542)	(0.00508)	(0.00594)
Mother's education	0.0315***	-0.00704	0.0241***	0.000456
	(0.00673)	(0.00849)	(0.00681)	(0.00791)
Asset index (ln)	0.0483**	-0.0242	0.0382	0.0302
	(0.0226)	(0.0267)	(0.0247)	(0.0284)
Takes tuition	0.307***	-0.0280	0.257***	-0.0950**
	(0.0924)	(0.107)	(0.0414)	(0.0479)
Teacher characteristics				
Age	0.0112***	-0.0131**	0.00223	0.00386
	(0.00284)	(0.00525)	(0.00269)	(0.00363)
Male	-0.340***	0.370***	-0.231***	0.202***
	(0.0503)	(0.0591)	(0.0689)	(0.0767)
BA	0.0192	0.0851	0.0686	-0.0984
	(0.0619)	(0.0721)	(0.0664)	(0.0753)
MA	0.0822	0.0294	0.144**	-0.180*
	(0.0886)	(0.105)	(0.0707)	(0.0977)
First Division	0.0796	0.0388	-0.0674	0.111
	(0.0856)	(0.0918)	(0.0683)	(0.0763)
Contract teacher	0.0265		0.0445	
	(0.0627)		(0.0499)	
_cons	-0.0538		-0.00964	
	(0.0579)		(0.0464)	
N	8185		6774	
No. of groups	62		71	
R^2	0.288		0.366	
F_diff all characteristics	6.855		2.351	
P_diff all characteristics	3.96e-20***		0.000462***	

Table 10: 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	88	5.27	176	63	2.80
95% confidence interval of predicted mean achievement score	22.68 - 28.32	32.58 - 35.20	0.70 -0.80	60.40 - 66.34	65.68 - 68.54	0.92 - 0.97
95 % CI of Cost per predicted achievement point (Rupees)	418 – 522	84 - 91	4.93 - 5.70	168 -185	61-64	2.73-2.88

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 11: 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,

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

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;

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

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:

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

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:

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

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

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

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

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

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

$$T_{ij} = (\beta_0 + \beta_1 \overline{TC}_r) + \beta_1(\overline{TC}_p - \overline{TC}_r)D_c + (\beta_2 + \beta_3 \overline{TC}_r)FC_i + \beta_3(\overline{TC}_p - \overline{TC}_r)D_c FC_i + \varepsilon_{ij} \quad (9)$$

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

Appendix 4 : Differentiating by type of contract teacher, Bihar – School FE

	(1) Contract	(2) Contract with and without training	(3) Full differentiation
Contract teacher	0.0688*		
	(0.0358)		
Contract teacher with no training		0.0680	0.0694
		(0.0463)	(0.0464)
Contract teacher with training		0.0691*	
		(0.0383)	
Contract teacher appointed pre-2006			0.0790*
			(0.0443)
Contract teacher appointed post-2006 without training			0.0629
			(0.0409)
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.