WHAT HAPPENS WHEN YOU PAY SHORTAGE-SUBJECT TEACHERS MORE MONEY? SIMULATING THE EFFECT OF EARLY-CAREER SALARY SUPPLEMENTS ON TEACHER SUPPLY IN ENGLAND

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FOREWORD BY SIR JOHN HOLMAN

As a former headteacher of a successful school I know the importance of specialist science and maths teachers in improving the life chances of all young people - and I know how hard it can be to find, and keep, these teachers.

We know that the most common reasons teachers give for leaving the profession are workload and behaviour. But science, particularly physics, and maths teachers leave the profession in even greater numbers than other teachers and this could be explained by the better paid opportunities outside the profession. The research reported here shows a simple finding: that paying early-career science and maths teachers a 5% salary supplement from 2010-2015 would have eliminated the maths and science teacher shortage. Not only that, but it would have done so at a lower cost to government than increasing the recruitment of new teachers, assuming that was even possible.

We also know that that there are significant inequalities in the distribution of specialist science teachers between schools. Our recent report, analysing job advertisements for science teachers, showed that schools with high levels or deprivation, low-attaining pupils or poor Ofsted ratings are significantly less likely to advertise for specialist biology, physics and chemistry teachers, which reinforces the inequalities in the system. This was underlined by the recent public account committee report highlighting the geographical variation in teacher turnover and retention.

So, we suggest that a salary supplement scheme for physics teachers, who prove to be the most difficult to recruit and retain, could be piloted in parts of the country where recruitment and retention is a particular challenge. I understand how implementing differential pay can be problematic for schools and for this reason any additional retention payment would need to be funded and administered by central government rather than forming part of the standard pay package
It would be a bold step for government to take, but a step with the robust evidence of this report behind it.

EXECUTIVE SUMMARY

Research suggests that the greatest point of leverage for policymakers looking to improve the quality of education is to ensure we have good teachers in our schools.[1]

Despite this, England currently faces a serious shortage of teachers in maths, science (especially physics), modern foreign languages and computer science.[2] This shortage is due in part to the increased rates at which early-career teachers are leaving the profession (Section 1). These shortages force school leaders, particularly those working in disadvantaged areas, to rely on less experienced, less effective teachers.[3]

Science and maths graduates are unusual among teachers in that on average their pay outside of teaching is higher than their pay inside teaching.[4] This is one important reason for the persistent shortages of teachers in these subjects. Indeed, a number of recent, carefully-controlled studies suggest that increasing the pay of shortage science and maths teachers increases retention in the profession.[5]

This paper applies the findings from these studies to the teacher labour market in England. More specifically, it attempts to answer the question: would introducing a 5% salary supplement for new science and maths teachers in the first five years of their career eliminate the shortage of teachers in these subjects, and how much would it cost? The effects of such a policy are simulated using data on real teachers between 2010 and 2015.

The results suggest that introducing such a policy in 2010 would have:

- Increased the supply of science teachers by 423 and maths teachers by 372 in 2015, through improving retention of those already in the profession.
- Eliminated entirely the overall shortage of science teachers experienced since 2010.
- Reduced substantially the deficit of maths teachers experienced in 2012 and 2013 and eliminated it entirely by 2014. Eliminating the shortages in 2012 and 2013 would have required the policy to be introduced earlier.

Moreover, the policy would have:

- Cost around £37m per year once fully rolled out. This is equivalent to around 5% of the annual cost of teacher training in England.
- Eliminated the shortage of teachers at a lower cost than recruiting more teachers, which is the government's current approach.
- More specifically, salary supplements increase the supply of experienced (>5 years since NQT) science and maths teachers at a lower cost than increased recruitment through five of the six main initial teacher training routes.
- For maths teachers, salary supplements increase the supply of experienced teachers at a lower cost than increased recruitment through all six main initial teacher training routes.

The findings from this analysis could inform policy in a number of ways. One option would be for schools to use their autonomy over pay to increase the remuneration of shortage-subject teachers. Another option would be for the government to increase the pay of shortage-subject teachers directly. Indeed, the government has recently announced plans to do just this through a scheme providing student-loan forgiveness for science teachers[6] and a separate scheme providing bonus payments to serving early-career maths teachers.[7] Section 6 of this report discusses whether these additional payments have been set at the right level. Briefly, our results suggest that the current policy of student loan forgiveness for science teachers is unlikely to be large enough to eliminate shortages, but the maths early-career payments are more likely to achieve the goal of eliminating shortages, if the policy is left in place for long enough.

In any case, this analysis makes clear the trade-off that we face. We can either have a small 5% pay gap between teachers of different subjects and eliminate the persistent shortage of science and maths teachers, or maintain the status quo around pay and continue to have a shortage of science and maths teachers. This is a debate which we need to have.

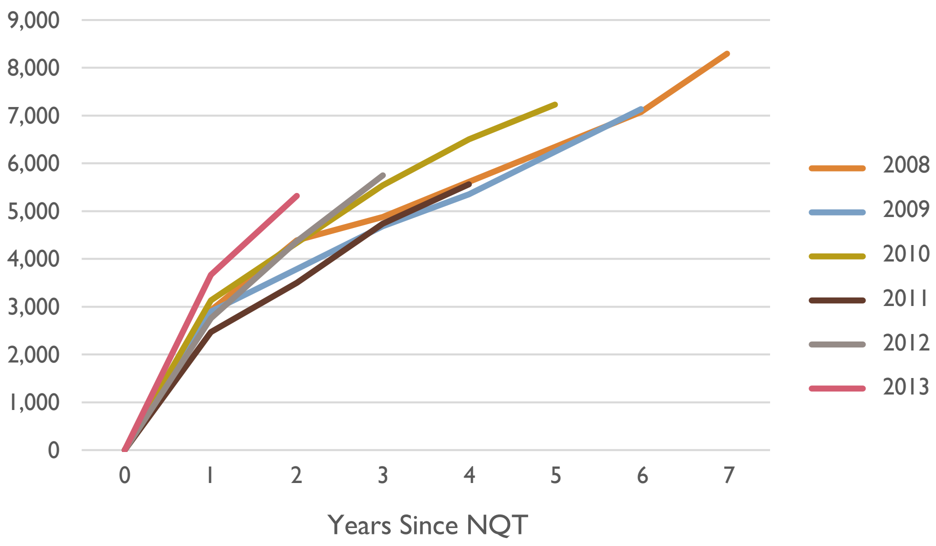
1. TEACHER SHORTAGES AND PAY IN ENGLAND

The Department for Education aims to "provide children's services and education to ensure opportunity is equal for all, no matter what their background or family circumstances."[8] Improving schools is a sensible place to start and careful empirical research suggests that the most important determinant of school quality is the quality of teaching.[9] Indeed, as Professor Eric Hanushek from Stanford University puts it, "No other attribute of schools comes close to having this much influence on student achievement."[10] Effective teachers also have a disproportionately large impact on the attainment of poorer pupils, meaning that good teachers also close the gap.[11] Ensuring a sufficient supply of high-quality teachers should therefore be a priority for education policymakers.

At present, however, we do not even have a sufficient supply of teachers in England. In May 2016, the government commissioned a detailed review of this problem from a group of academics led by Professor Alan Manning from the London School of Economics. Their exhaustive 162-page report concluded that maths, science (especially physics), computer science and modern foreign language teachers are all in short supply.[12] Figures from the government's own Teacher Supply Model also indicate that there has been a shortage of maths teachers at least since 2012 and an overall shortage of science teachers at least since 2013. Neil Carmichael MP, former chair of the Education Select Committee, has warned that without action from policymakers this shortage will become a crisis.[13]

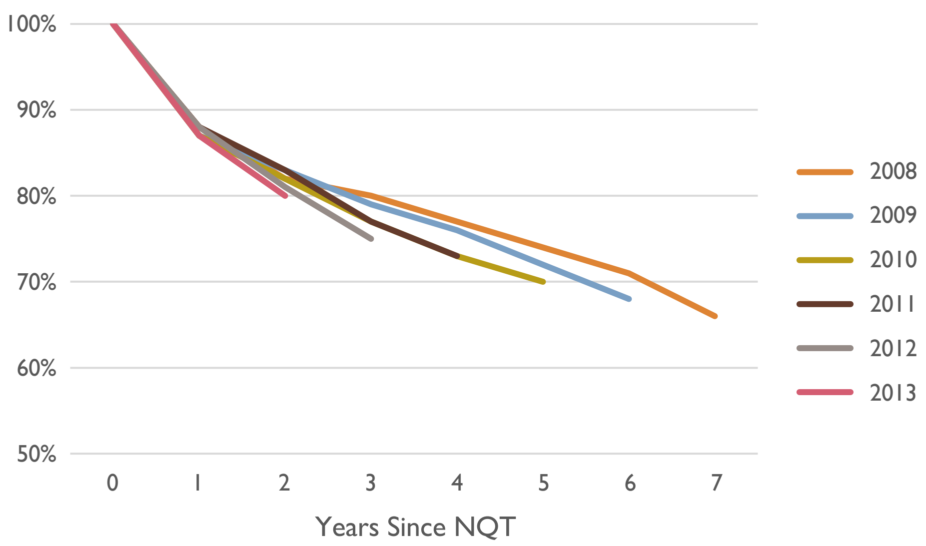
This shortage of teachers also affects the quality of teaching in our schools. Empirical research shows that, on average, teachers get rapidly better at their jobs during the first three years of their career and continue to show measurable improvement for five or ten years after qualification.[14] However, recent data (Figure 1, Figure 2) shows that retention of new teachers is getting steadily worse with each new cohort of trainees. The most recent data available show that, among those who entered the profession in 2012, around 20% (5,320 teachers) had left by 2015. Every teacher that leaves within their first few years on the job has to be replaced with another new teacher, creating a merry-go-round of inexperienced teachers, and holding down the overall quality of the teaching workforce.

Figure 1: Number of Cohort No Longer in Teaching



Note: Cohorts after 2013 not shown due to of lack of follow-up data.
Source: School Workforce in England SFR21.

Figure 2: Proportion of Cohort Still in Teaching



Note: Cohorts after 2013 not shown due to of lack of follow-up data.
Source: School Workforce School Workforce in England SFR21.

In general, the best way to increase teacher retention is to improve the quality of working conditions for teachers.[15] However, maths and science teacher shortages have a further, distinctive cause. Maths and science graduates tend to earn more in jobs outside of teaching, whereas graduates in other subjects tend to earn more in teaching jobs (Table 1).[16] Maths and science teachers therefore face an additional "pull" from other job opportunities, over and above the "push" that teachers feel from the challenging nature of the job. This pull is likely to be particularly strong during the first few years after graduation, when it is arguably easier to switch careers. Research using data on English schools shows that such outside wage gaps damage the quality of schooling through their negative effects on teacher retention.[17]

Table 1: Average Career-Wide Earnings Inside and Outside Teaching by Degree Subject

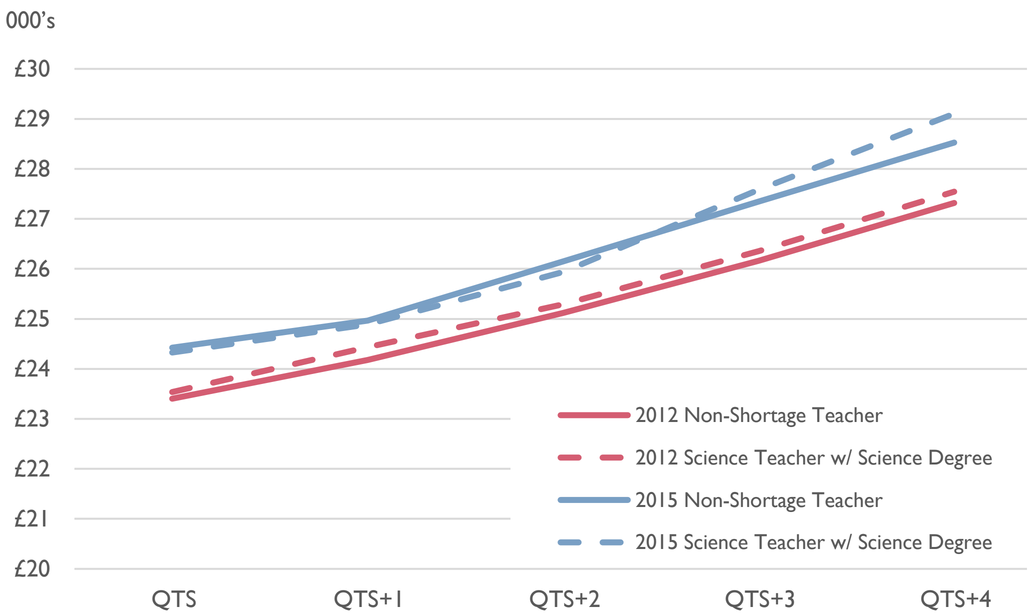
	Degree Subject	Median Salary of Teachers	Median Salary of Non-Teachers	Difference (for Teachers)
Non-teachers are paid more	Physics	£31,600	£38,000	-£6,400
	Maths	£35,500	£40,000	-£4,500
	All Science	£32,000	£35,000	-£3,000
	Biology	£31,000	£32,600	-£1,600
Teachers are paid more	English	£28,000	£25,300	£2,700
	MFL	£31,200	£27,700	£3,500
	History	£34,100	£29,400	£4,700
	P.E.	£33,100	£25,000	£8,100

Note: Shows only selected subjects. Chemistry not shown due to small sample sizes. This should not be interpreted as causal evidence, because differences in pay may be due to the type of people who choose to go into teaching, as well as being due to the job itself. Source: [18]

Although higher outside pay creates additional difficulties for retaining science and maths teachers, it also points towards a simple potential solution: pay them more. Teacher pay in England has recently been reformed in a number of ways. Prior to 2014, teachers not in leadership positions moved one point up the Main Pay Scale with each additional year of service. Since 2014, however, schools in England have been free to determine their teachers' pay based on an appraisal of their performance, within the pay ranges (bands) determined by government.[19] Automatic progression based on experience has stopped. New or inexperienced teachers are generally paid on the "Main Pay Range" which was between £22,917 and £33,824 for Non-London schools in 2017. The public sector pay cap, which was introduced the year before the new pay flexibilities, has limited increases in the minimum and maximum pay for each pay range to 1% per year. Academies, which now account for the majority of secondary schools, have complete discretion over staff pay. The government has also introduced a range of subject-specific bursaries and scholarships that provide financial incentives for shortage-subject teachers to train. However it should be noted these bursaries and scholarships do not incentivise retention once training is complete because they leave the ratio between pay in teaching and pay outside teaching (the "outside pay ratio") untouched.

Given the considerable increase in schools' autonomy over teacher pay, it could be argued that schools will already be responding to science and maths teacher shortages by increasing wages. However, there is some doubt about whether schools are using their pay freedoms. A 2014 survey of academies, for example, found that while 24% had changed staff pay structures, 76% had not yet done so.[20] Evaluations of these pay reforms have so far found only limited evidence of changes in the distribution of teacher pay resulting from these new freedoms[21]. Qualitative research suggests that many headteachers have stuck with local authority pay scales in order to maintain consistency with other nearby schools.[22] To provide some further evidence on this point, Figure 3 compares pay for early-career science teachers with science degrees (dotted lines) to teachers working in non-shortage subjects (solid lines). On the left of the graph are teachers who have only recently received NQT status. Teachers further to the right are more experienced. If schools were using their autonomy over pay to respond to shortages of science teachers, then we would expect to see scientists with science degrees being paid more than non-shortage teachers. Figure 3 shows that in 2015, the year after the reforms, science teachers with science degrees were being paid the same as non-shortage colleagues in the first four years after qualification, but slightly more in the fifth year (blue line). Adding the pay differences across the five years, the total for science teachers with a science degree is just 0.3% higher than for their non-shortage colleagues. Moreover, the picture is little different to the situation before the pay flexibilities were introduced in 2013 (pink lines). There is therefore little evidence to date that schools are using their autonomy over pay to respond to subject specific shortages.

Figure 3: Comparing Average Teacher Pay



Note: Only includes full-time, permanent contract teachers. Source: School Workforce Census.

During October 2017, the government announced two new policies to directly increase the pay of early-career, shortage-subject teachers. First, they announced that science and modern foreign language teachers working in priority areas would be eligible for a "loan forgiveness" scheme which reimburses their student loan repayments across the first ten years of their career. [23] The Department for Education claim this will be worth around £540 per annum for the typical teacher in their fifth year in the profession. Second, the government announced the mathematics early-career payments scheme. Maths teachers training in the 2018-19 academic year will receive £5,000 in their third and fifth years of teaching if they work continuously in state funded schools in England following qualification. This figure increases to £7,500 for those working in certain priority areas. [24] Policies like these seem a sensible response to the current shortages of science and maths teachers. However, we do not yet have any research on whether they have been set at the right value in order to eliminate shortages.

Given the importance of teachers, the current shortage, and the apparent importance of pay, this paper evaluates the costs and benefits of paying maths and science teachers a salary supplement during the first five years of their careers, and seeks to identify the optimal value of such a payment. The costs of such a policy consist largely of the additional salary costs which would be paid ultimately by the taxpayer. The benefits are the higher number of experienced teachers generated through enhanced retention. For schools, this analysis can be used to inform decisions about how much to pay teachers with different degree subjects. For central government, this analysis can be used to evaluate their current approach to setting the national pay ranges, which is currently done without regard to subject taught, and to consider the value of other policies, such as student loan forgiveness and early-career payments.

2. SALARY SUPPLEMENT POLICIES FOR REDUCING SUBJECT-SPECIFIC TEACHER SHORTAGES

Many school systems have implemented policies that increase the pay of those teaching in subjects in which there is a teacher shortage.[25] The aim of such policies is usually to increase retention, either in a specific "hard to staff" school, or in the teaching profession as a whole. Three such policies have now been evaluated using careful observational research designs. The aim of this section is to identify and quantify the relationship between the pay and retention of shortage-subject teachers in order to simulate the effect of a similar policy in England.

NORTH CAROLINA BONUS PROGRAM

Clotfelter et al (2008) evaluated the impact of the North Carolina Bonus Program (NCBP) on the retention of shortage-subject teachers in hard to staff schools. Between 2001 and 2003, NCBP awarded an additional $1,800 per year (a 4-5% increase in pay) to teachers in the state of North Carolina (population 8.2m in 2001) who fulfilled the following two criteria:

1) They were certified (qualified) in the shortage subjects of maths, science and special education (SEN) and were teaching those subjects…

2) …in middle or high schools[1] that had either 80% or more pupils on free or reduced price lunch[2] or 50% or more pupils performing below grade level in both Algebra and Biology.

The researchers compared the hazard rates[3] of eligible teachers leaving before and after the policy was introduced, controlling for a wide range of variables that were measured in their data. They then "subtracted" from this any changes (improvements) in hazard rates that they observed among ineligible teachers in the same schools over the same period. The researchers assume that the eligible teachers would have shown the same change (improvement) in hazard rates as these ineligible teachers in their school, due to e.g. shared effects of school leadership, even in the absence of the policy. Thus, this part of the variation in retention could not have been caused by the policy itself. This helps rule out alternative explanations (other than the policy) for changes in retention among the eligible groups. They then also subtracted any changes in hazard rates among eligible teachers (fulfilling criteria 1) working in schools which were narrowly ineligible for the policy (just missed out on criteria 2). Again, the assumption was that the eligible teachers in ineligible schools would have shown this change in hazard rates even in the absence of the policy, by virtue of having the same certification status. Thus, this part of the variation in retention also could not have been caused by the policy itself. The researchers found that the 4-5% pay increase reduced the probability of departure from a given school in a given year by 17% for eligible teachers. Economists typically express the way in which a % change in one variable affects another variable as an "elasticity". In this case, the elasticity of turnover with respect to salary can be calculated as -17/4.5=-3.8. This can be interpreted as: "For every 1% increase in pay, there is a 3.8% reduction in turnover."

1 Pupils aged between 12 and 18

2 This is similar to Free School Meals in the UK and is used as an indicator of disadvantage

3 The hazard rate is the probability that the individual leaves in a given year, given that they have not yet left. It can be thought of as the probability of them leaving at a single point in time.

FLORIDA CRITICAL TEACHER SHORTAGE PROGRAM

Feng & Sass (2016) evaluated the impact of the Florida Critical Teacher Shortage Program (FCTSP) on the retention of shortage-subject teachers (science, maths, modern foreign languages) in Florida State schools. Between 1986 and 2002, after which the FCTSP was scaled back, the policy awarded an average of $2,000-$3,000 per year in student loan forgiveness (around 3.4% of average net pay) to eligible teachers in Florida (population 16.3m in 2001). The maximum award per teacher was $10,000 across four years, meaning that receipt was concentrated among early-career teachers. To be eligible, teachers had to be certified in a shortage-subject area and have taught that subject for at least ninety days that year. The researchers compared hazard rates (risk of leaving the profession) before and after the policy was introduced for a given subject, controlling for a range of other variables that were measured in their data. They also "subtracted" the changes in turnover observed for teachers in ineligible subjects over the same period, on the assumption that eligible teachers would have experienced this change even in the absence of the policy. The researchers found that the ~3.4% increase in net pay resulted in an 11.1% reduction in maths teachers leaving Florida schools. This gives an elasticity of wastage (leaving teaching) with respect to salary of -11.1/3.4=-3.3. This can be interpreted as: "For every 1% increase in pay there is a 3.3% reduction in wastage". They also looked separately at science and found the policy resulted in an 8.6% reduction, which gives an elasticity of -2.5. This can be interpreted as: "For every 1% increase in pay, there is a 2.5% reduction in wastage."

GEORGIA HOUSE BILL 280

Bueno & Sass (2016) evaluated the impact of the measures introduced in the Georgia State Legislature 2009 House Bill 280 (HB280) on the retention of shortage-subject teachers in Georgia State schools. Since 2011, HB280 awarded an average of $3,953 in additional pay per year to all eligible teachers in the State of Georgia (population 9.6m in 2009). The average non-supplemented pay over the first five years of a teacher's career in Georgia at this time was $37,985, making the supplement equivalent to a 10.4% uplift. To be eligible, teachers had to fulfil two criteria:

1) They were certified (qualified) in the shortage-subjects of maths, science and were teaching those subjects in a middle or high school, and
2) They were still in the first five years after qualifying as teachers

The researchers compared hazard rates (risk of leaving the profession) before and after the policy was introduced for a given subject, controlling for a range of other variables that were measured in their data. They also "subtracted" the changes in turnover observed for teachers in the first five years of their career but who were teaching ineligible subjects over the same period. They also subtracted the change in hazard rates for teachers in eligible subjects who were not in the first five years of their career. The methodology is therefore similar to Clotfelter et al (2008). The researchers found that the 10.4% increase in net pay resulted in a 35% reduction in teachers leaving Florida schools. This gives an elasticity of wastage (leaving teaching) with respect to salary of -35/10.4=-3.4. This can be interpreted as: "for every 1% increase in pay there is a 3.4% reduction in wastage."

These three non-experimental studies are not perfect, in that they cannot rule out the differences in retention rates being driven by other (confounding) variables that are not measured in the data and have not been controlled for.[4] Nevertheless, there are two reasons to think that these studies do provide good evidence on the link between pay and retention for shortage-subject teachers. First, although they cannot control for everything, they are able to control for a wide range of variables, including those not measured in the data.[5] As observational research designs go, these are quite strong. Second, the three studies, which look at different policies, using different data sets, in different states, show a high level of agreement. Table 2 shows that the elasticity estimates vary between 3.8 and 2.5. Among the estimates that look specifically at wastage, the range is smaller still at between 2.5 and 3.4. As discussed in Section 1, the goal of policy should be to increase retention in the profession as a whole. This makes the elasticity of wastage estimates more relevant. The mean value for these is -3.1, which can be interpreted as: "For every 1% increase in pay for a shortage-subject teacher, there is a 3.1% reduction in the number of teachers quitting the profession. This is the estimate that will be used to simulate the effect of introducing such a policy in England".

Table 2: Summary of Elasticity Estimates

	Elasticity of Turnover	Elasticity of Wastage
Clotfelter et al (2008)	-3.8	
Bueno & Sass (2016)		-3.4
Feng & Sass (2016) Science		-2.5
Feng & Sass (2016) Maths		-3.3
Mean	-3.8	-3.1

4 A randomised controlled trial (RCT) would eliminate all such concerns, at least in expectation. However it seems unlikely that any government agency would agree to pay some of its teachers more than others, based on the outcome of a random draw in a lottery. It is therefore unlikely that we will ever get evidence from an RCT on this point.

5 Any time-invariant teacher-level unmeasured differences are dealt with by comparing teachers to themselves over time. This is known as a "fixed effect approach". Any time-varying unmeasured variables that are common between eligible teachers and the various ineligible comparison groups are also dealt with through "subtracting" the differences. This is referred to by statisticians as double-difference or triple-difference strategies.

3. METHOD AND ASSUMPTIONS

The aim of this section is to simulate the effect of introducing a salary-supplement for shortage-subject teachers to evaluate the effect this would have on both the overall supply of teachers and the supply of experienced (5+ years) teachers in England. Any exercise in simulation requires going beyond the empirical data. In order to do this, assumptions have to be made. Ideally, these assumptions will be kept to a minimum and clearly stated and justified. My approach here is to use the data as far as possible. I therefore simulate the effect of the policy as if it had been implemented in 2010 and test whether it would have eliminated the actual historic teacher deficits in subsequent years. I will also state all the major assumptions I make in ***bold***.

There are a number of options for how to design a shortage-teacher salary-supplement policy: which years it should be paid in; how much it should be; and which subjects are eligible. Running the simulation using historical data imposes some constraints on these choices, since the School Workforce Census data set is only currently available for six years (2010-2015). In order to see the full effects of the policy, I therefore choose a policy-design that is similar to HB280 in that it ***provides a salary supplement only for teachers in the first five years after qualification***. In any case, this is a sensible design since early career teachers seem more sensitive to pay.[26]

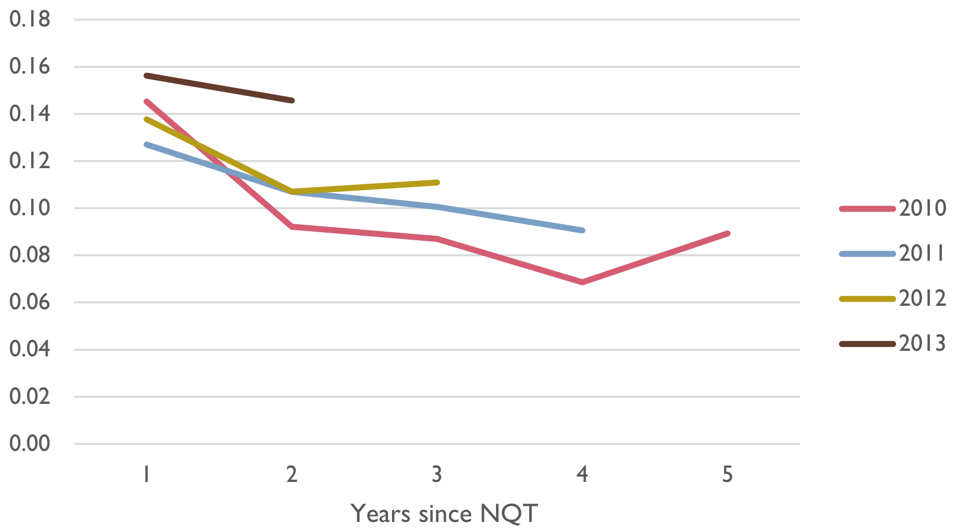
In Georgia, teachers are paid on a standardised state-wide salary schedule with a given teachers' pay determined by their number of years of experience in teaching. The HB280 policy effectively paid all teachers with less than six years of experience the same amount as a teacher with six years of experience. One option would be to copy this aspect of HB280 for this simulation. However, the design of HB280 means that the salary supplement was larger in the first few years of the teacher's career, as it had to make up a bigger gap with the six year pay figure, and smaller in later years. This introduces additional complexity into the analysis. I therefore adopt a simpler policy design, which increases the pay of shortage-subject teachers by a fixed percent in each of the first five years after qualification. For the sake of argument in this paper ***I adopt a realistic assumption of a 5% supplement***.

In order to quantify the shortage of teachers in a given subject in a given year, I will use the difference between the target for post-graduate initial teacher training new entrants and the numbers recruited in each year taken from the Initial Teacher Training (ITT) Census Main Tables.[27] Because the targets for recruitment are built on Teacher Supply Model calculations of the overall need for additional teachers in each subject, this provides a useful benchmark for the size of the deficit in each year. In order to keep the analysis manageable, I choose to only make science and maths teachers eligible for the salary supplement. The estimates of the need for new science teachers in the ITT Census are not split out into chemistry, biology and physics until 2014/15. Moreover, the fields in the School Workforce Census do not reliably differentiate whether science teachers spend some or all of their time teaching one science or a mix of all three. I therefore analyse science teachers as a single group and do not differentiate between the three different sciences.

The overall retention data shown in Figure 1 and Figure 2 is taken from the School Workforce in England tables released by the government.[28] These are made from two sources: the School Workforce Census, which is an annual census of school staff in England, and the Teacher Pension Records data. Where data on a specific teacher is missing in the School Workforce Census, data from the pensions records (i.e. are they still paying into a teachers' pension scheme?) can be used to assess whether they are still working in the profession. In order to generate the equivalent tables for maths and science teachers, I rely entirely on the School Workforce Census. Comparing the table for all teachers generated entirely from SWC with the government version reveals that the SWC understates teacher retention by about 10%.[6] This means that my analysis will also understate the increase in teachers that would be created by the salary supplement policy, in the sense that I will be scaling up a number which is itself an underestimate.

The tables from the School Workforce Census (SWC) show the number of each science/maths cohort of NQTS (2010, 2011, etc) retained one year after qualification, two years after qualification and so on, through to five years after qualification. I then calculate the hazard rates[7] for each cohort in each period. The hazard rate is the probability of leaving the profession in a given year, given that somebody is still in the profession in that year. Figure 4 shows the hazard rates for the first four cohorts of science NQTs included in the SWC, Figure 5 shows the same for maths. Both figures show that the hazard of leaving is high initially, declines but then begins to level off, and then increases slightly in later years. Each new cohort has increasingly high hazards in any given year, reflecting declining retention rates.

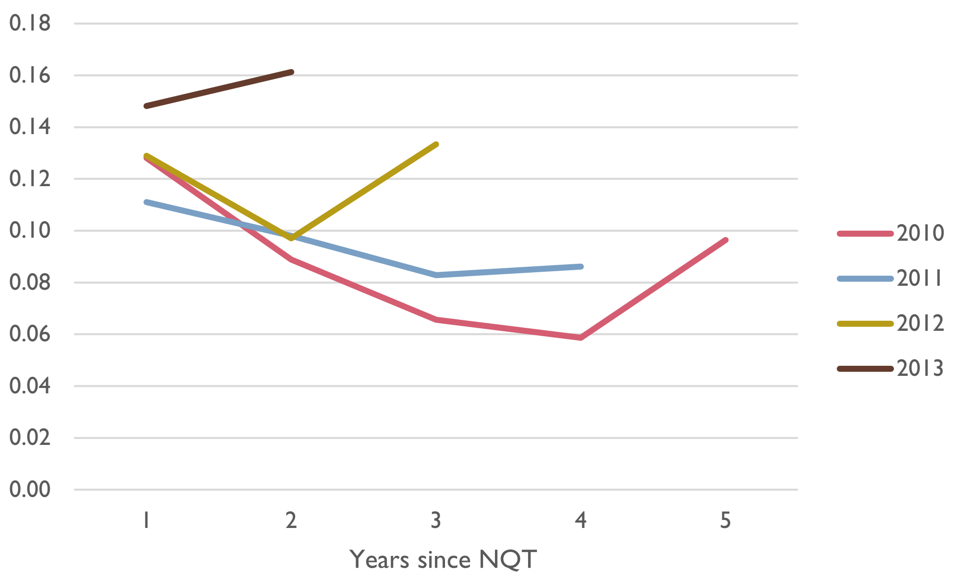
Figure 4: Science Teacher Hazard Rates by NQT Cohort



6 NB: saying that retention is underestimated by 10% means that it is underestimated by one tenth. This does not mean it is underestimates by 10 percentage points.

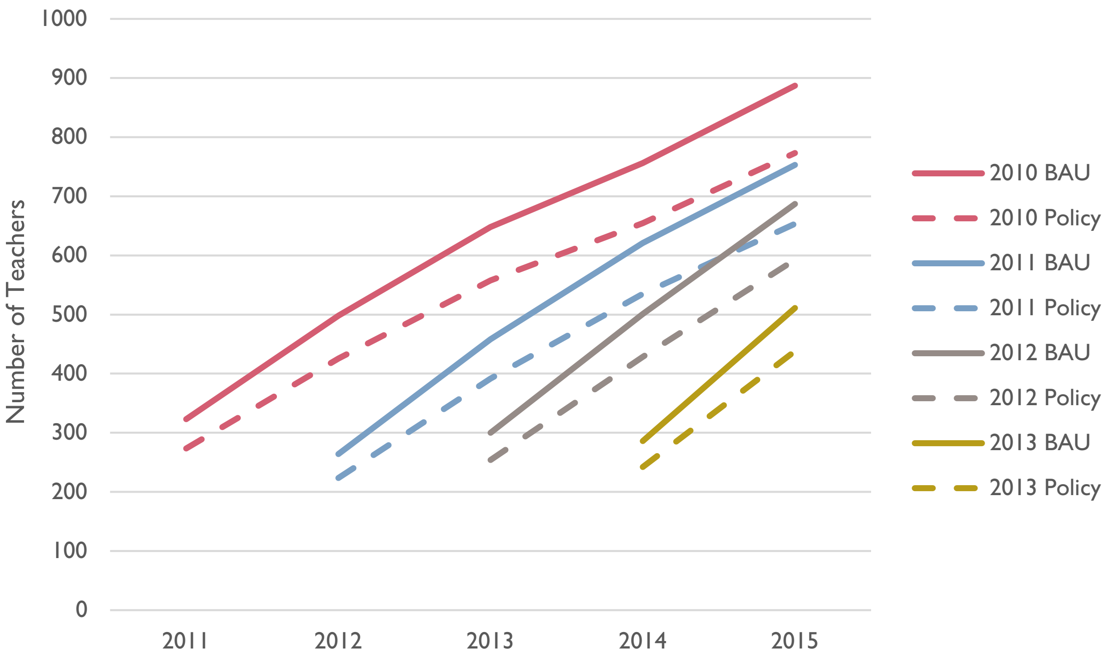
7 The hazard rate is the probability of individuals leaving in a given year, given that they have not yet left. It can be thought of as the probability of them leaving at a single point in time.

Figure 5: Maths Teacher Hazard Rates by NQT Cohort



Once I have done this for each cohort in each year, I then adjust the hazard rates to reflect the impact of the policy. A 5% pay increase for science and maths teachers, ***assuming a -3.1 elasticity*** (Table 2) of wastage with respect to pay, implies a 15% reduction in the hazard rate. The adjusted hazard rates can then be used to adjust the wastage for each cohort in each year. Because the elasticity estimates in the studies in Section 2 are derived from Cox Proportional Hazard models, it is already implicitly assumed that ***a given reduction in the probability of leaving the profession due to an increase in pay is assumed to be evenly distributed across each year the policy is in place.*** The difference between the number of teachers retained in each cohort in the "Business As Usual" (BAU) and the number retained in the "policy" scenario then gives an estimate for the additional supply of teachers in a given year. Figure 6 shows the cumulative wastage for science teachers by cohort in both the BAU and policy scenario. The gaps between the solid and dotted lines of a given colour represent the additional retention within a single cohort. The maths version of this chart (not reported here), looks very similar. ***I am assuming here that the increased pay available does not incentivise more people to train in each cohort.*** Given that higher pay would likely attract slightly more people into teaching, this again means that my estimates of additional teacher supply will be conservative.

Figure 6: Cumulative Science Teacher Wastage by Cohort

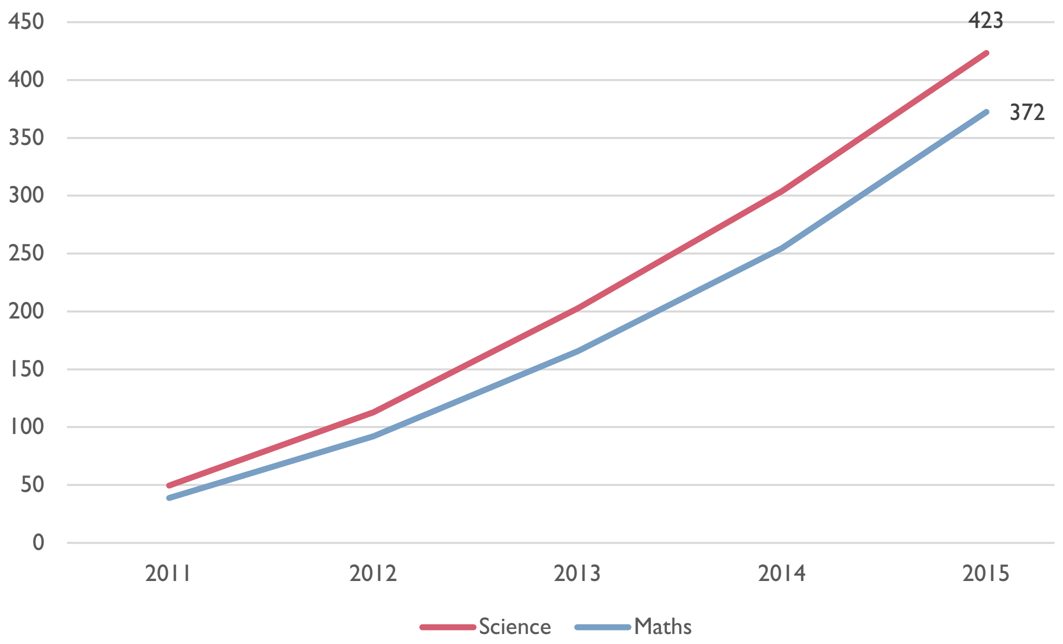


In this and later stages of the analysis ***I am also assuming that when teachers reach their sixth year after qualification, their hazard rates return to the rates observed in the data.*** If teachers in the policy scenario are "hanging on" in teaching to get the additional pay in all the years in which they are eligible, they may leave in greater numbers once the supplement is withdrawn, making this an unrealistic assumption. On the other hand, if the higher wastage rate among maths and science teachers is explained by the higher outside pay ratio they face, then it could be argued that this is a realistic assumption, since both the inside (teaching) and outside (non-teaching) pay will be the same from year six onward in the policy scenario, as it would have been in the BAU scenario. A similar policy in the US withdrew salary supplements after five years and the evaluation showed that in-school retention among eligible teachers returned to the same rate as among ineligible teachers.[29] This provides some empirical evidence that my assumption here is justified.

4. BENEFITS: EFFECTS OF THE POLICY ON TEACHER SUPPLY IN ENGLAND

Figure 7 shows the number of additional in-service teachers created in each year of the policy. The policy is implemented in 2010 but the salary supplement yields its first additional teachers the following year. In 2011 only one cohort is benefiting from the policy, in 2012 two cohorts are, and so on. Science has a larger cohort in each year, which explains why the number of additional teachers is higher than for maths.

Figure 7: Additional In-Service Teachers Due to Policy



How significant is this increase in teacher supply? This can be assessed by comparing the number of additional teachers in each year with the size of the recruitment deficit from the ITT Census.[8] Figure 8 shows the science teacher balance in each year. A number above zero means that the ITT science recruitment targets for that year were exceeded; below zero indicates a deficit. In 2011, the target for science teacher recruitment was exceeded. Remember, this is across the three sciences, so this may reflect a surplus of biologists cancelling out a deficit of physicists. However this surplus drops almost to zero in 2012, and then becomes a deficit in 2013, which gets larger in 2014 and 2015. However in the salary-supplement scenario, these deficits are eliminated entirely and there is a surplus of around 100 teachers by 2015. Additional analysis, not reported here, shows that reducing the salary supplement to 4% also eliminates the deficit in all years, at a lower cost.

8 The recruitment target in the ITT Census reflects the size of the expected shortage in the next year plus an additional number that reflects the expected rate of teachers who do not progress from ITT to NQT status. I therefore deflate the recruitment targets to reflect the conversion rates used in the Teacher Supply Model in order to calculate the overall shortage of teachers in each year.

Figure 8: Science Teacher Balance

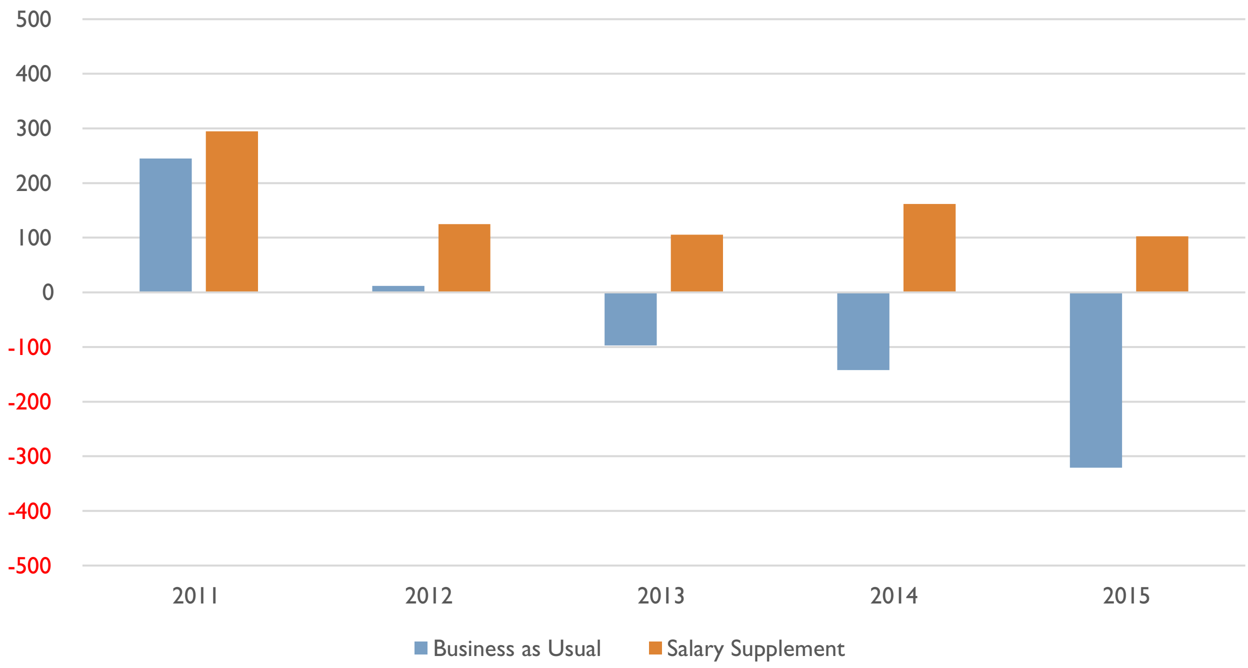
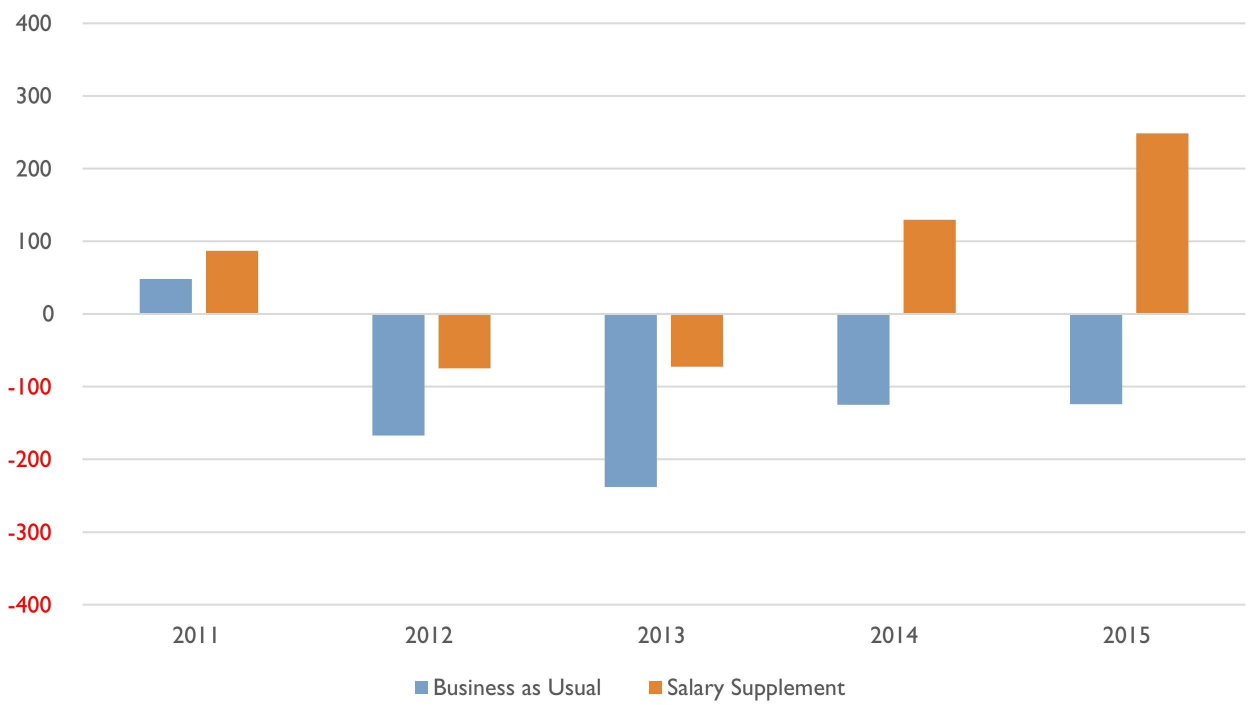


Figure 9 shows the same results but for maths teachers, with the supplement again set at 5%. The maths teacher deficit opened up much more abruptly than the science teacher deficit and therefore outstrips the build-up of additional teachers due to the policy in 2012 and 2013. In 2014 and 2015 however, the policy eliminates the deficit entirely. Eliminating the deficit in all years requires a very large increase in the supplement to generate a faster build-up of additional teachers, or beginning the policy earlier and accepting surpluses in the years preceding 2012.

Figure 9: Maths Teacher Balance



In summary, a 5% salary supplement for shortage-subject teachers in all cohorts beginning after 2010 would have eliminated the overall deficit in science teachers in every year, and replaced a circa 100 maths teacher deficit with a circa 250 teacher surplus by 2015. It is important to note that, if the assumptions made in the last section are correct, the number of additional teachers created by the policy continues to grow even after the policy reaches full coverage (five cohorts) of teachers in 2014 and the first cohort has the supplement removed. This is because each cohort for whom the supplement is removed still has a higher number of teachers in it (compared to the BAU scenario) in all subsequent years and new cohorts are continually entering the workforce. The total number of additional teachers therefore continues to grow, albeit more slowly than during the first five years of the policy, until the first cohort to benefit from the policy reaches retirement.

5. MONETARY AND OPPORTUNITY COSTS OF THE POLICY

Supplementing the salaries of shortage-subject teachers will cost the taxpayer money. The first component of this cost is the salaries (including supplement) of the additional teachers that are retained due to the policy. The second is the cost of the 5% supplement for all the teachers that would have been in the profession anyway - known as the "deadweight" of the policy. Table 3 shows the build-up of the costs over time as the policy reaches full coverage (five cohorts at once). After full coverage is reached in 2014, the cost will level off, varying only with the size of the cohort and general pay levels. The total cost of the policy would therefore have been around £37m per annum by 2014, composed of £19.3m for science and £17.5m for maths. Around half of this cost is deadweight. For context, this is equivalent to around 2% of the total cost of the pupil premium policy in that year, or around 5% of the annual cost of teacher training.[30]

Table 3: Total Annual Cost of the Salary Supplement Policy (£, million)

	2010	2011	2012	2013	2014
Total Annual Policy Cost Science	2.51	6.0	10.08	14.77	19.37
…of which Deadweight	2.51	4.7	7.0	8.9	10.21
Total Annual Policy Cost Maths	2.23	5.3	8.87	13.2	17.54
…of which Deadweight	2.23	4.3	6.35	8.42	9.84
Total for Science and Maths					36.91

Knowing the monetary cost of the policy is useful, since it tells us how much it would cost to achieve the reductions in teacher shortages set out in the previous section. However, given that the government is committed to eliminating teacher shortages anyway, it is arguably more interesting to think about the opportunity cost of the policy. That is, is there a cheaper way of achieving the same thing?

One sensible way of benchmarking this is to calculate the cost of achieving the same number of additional experienced (5+ years) teachers through increased recruitment. To simplify the analysis, I look only at the 2010 cohort, which would have been the first to benefit from the policy. I talk through the method for science teachers but present results for both science and maths.

My analysis shows that the salary supplement policy would have created 114 additional experienced (5+ years) science teachers within five years from the first cohort alone. For the sake of argument, I assume in this section that the government is somehow able to recruit enough additional teachers to generate the same number of experienced teachers within five years, without spending any more on salaries, bursaries or other incentives. This is a generous assumption, given that the government has consistently under-recruited in recent years. This means that the only additional cost to the taxpayer of the increased recruitment policy would have been the salaries of the additional teachers recruited. Note however, that the government would have had to over-recruit additional teachers in 2010 since for every 100 additional science teachers recruited in 2010, only 60 would still have been teaching by 2015. The precise number of additional teachers that would have to be recruited depends on which training route the teachers go through, since each has a different dropout rate. Table 4 shows the five year retention rates by training route, taken from recent work by Ellen Greaves and colleagues[31], and the corresponding numbers of additional teachers that would have to be recruited in the 2010 cohort in order to generate 114 additional experienced science teachers five years later. This ranges between 160 for School Centred ITT (SCITT) and 278 for Teach First.

Table 4: Additional Recruits Required, by Training Route

	HEI-led PG	SCITT	SD Salaried	SD Unsalaried	Teach First
5 Year Retention Rate	52%	71%	65%	70%	41%
Additional Recruits Required	219	160	175	163	278

Source: [32]

The monetary cost of the additional recruitment policy for each route will be a combination of the costs of recruiting/training teachers through that route and the cost of paying their salaries up until year five. Allen et al provide estimates of the average and maximum central cost of training teachers through each route in the 2013/14 academic year, including the bursaries and scholarships available.[33] This will be an overestimate because I am using data for the 2010 cohort, but the comparison between the two policies will remain fair. Because science was a shortage subject in 2013/14, there were generous scholarship and bursary payments available for those training as science teachers. ***I therefore take the mid-point between the maximum and average cost as a reasonable assumption for the cost per science teacher trained.*** I then add to this the estimate of the cost per school for each training route, which gives me an estimate of the total training cost for each training route. The salary costs are composed of the total pay of the 114 teachers that make it to five years plus any salary costs incurred by the other teachers before they drop out. In order to simplify the calculations, I assume that all the teachers who do not make it to five years drop out after two years in the profession. Combining these figures gives the results in Table 5 below. The cost of creating an additional experienced science teacher through increased recruitment (assuming it can be done) range from £185,574 (School Centred Initial Teacher Training) to £273,109 (Teach First). The higher costs for the latter are driven by the higher dropout rate. The cost of each additional experienced maths teacher created through additional recruitment varies from £155,601 to £228,725.

Table 5: Costs per Additional Experienced Teacher by Training Route (£, thousand)

	HEI-led PG	SCITT	SD Salaried	SD Unsalaried	Teach First
Salary Costs: Teachers That Stay Five Years	15,403	15,403	15,403	15,403	15,403
Salary Costs: Teachers That Leave Before Five	4,996	2,211	2,915	2,320	7,789
Total Training Costs	6,569	5,043	6,231	5,450	10,147
Cost per Additional Experienced Teacher	221	186	201	190	273

Note: Cost per Additional Experienced Teacher is the sum of the first three rows divided by 114. Figures shown to nearest thousand £. Source: [34]

In order to calculate the cost per additional experienced science teacher in the 2010 cohort, I add together the cost of paying all the BAU teachers 5% more than they would otherwise have received (the deadweight cost of the policy), the salary costs of each additional teacher retained, and the 5% salary supplement for each additional teacher trained. I am making the ***assumption here that the salary supplement policy does not incur any administrative costs***. This is clearly unrealistic, but I expect the average administrative cost to be very low once spread over all the additional teachers. Table 6 show the annual and cumulative cost of the policy for the 2010 cohort only.

Table 6: Annual and Cumulative Cost of the Policy for 2010 Cohort (£, thousand)

	2010	2011	2012	2013	2014
Supplement for BAU Teachers	2,514	2,364	2,303	2,311	2,314
Salary for Additional Teachers	0	1,232	1,936	2,646	3,202
Supplement for Additional Teachers	0	62	97	132	160
Total Annual Cost	2,514	3,658	4,336	5,089	5,677
Cumulative Cost	2,514	6,171	10,507	15,596	21,273
Cost per Additional Experienced Teacher					187

Note: Figures shown to nearest thousand £. The total annual cost is the sum of the first three rows.

We can now compare the cost of creating an additional experienced teacher through the salary supplement policy versus the recruitment policy, across training routes. Figure 10 shows that the salary supplement policy is a cheaper way of creating additional experienced science teachers than recruiting additional teachers through any other routes, except SCITT. If the government did 100% of the additional recruitment through SCITT then the recruitment policy would be better value for money. However, since SCITT has only ever been a small share of ITT allocations, and it will not be appropriate or desirable for all trainees, it is likely the government would have to rely, at least in part, on the more expensive routes such as HEI-led PG and Teach First. In this case, the salary supplement policy would be better value. It's also worth repeating at this point that I am making the generous assumption that the government is actually able to recruit the additional teachers they would need to close the deficit through the increased recruitment policy, which has not proved possible in recent years. For science teachers then, the salary supplement policy represents good value-for-money.

Figure 10: Total Cost per Additional Y5 Science Teacher (£, thousands)

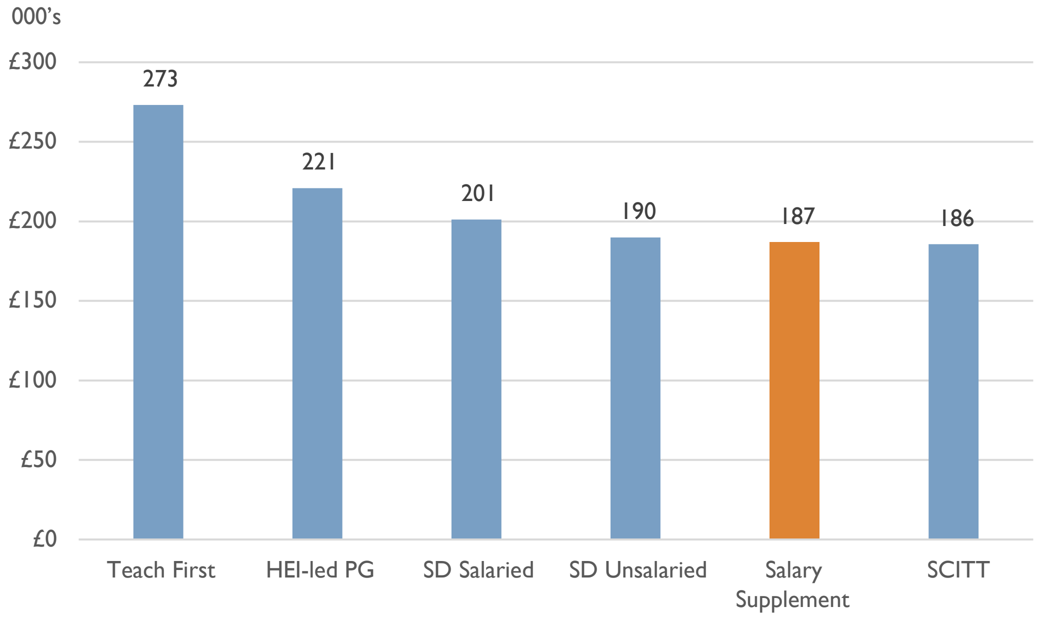


Figure 11 shows the same analysis but for maths teachers. In this case, the salary supplement is unambiguously better value for money when it comes to creating additional experienced teachers, irrespective of which training route additional recruits would have been trained through.

Figure 11: Total Cost per Additional Y5 Maths Teacher (£, thousands)

6. DISCUSSION

Introducing a 5% salary supplement for maths and science teachers during the five years after achieving NQT, beginning with the 2010 cohort of NQTs, would likely have eliminated science teacher shortages in all subsequent years and eliminated maths teacher shortages by 2014. The estimates are conservative in the sense that increasing the pay of early career teachers would likely increase the number of people training to be teachers to begin with, but this is not incorporated in the simulations presented here.

This policy would have cost £37m per annum once it had reached full coverage in 2014, which is equivalent to around 5% of the money that the DfE spends on teacher training each year. This salary supplement policy would also be cheaper than trying to close the deficit of teachers in these subjects through increased recruitment, which is the government's current approach. It is also more likely to be successful than the current approach, which has failed to recruit enough teachers for several years in a row.

There are a number of options for how such a policy could be implemented. Schools with complete autonomy over pay could use this information to set up or adjust their own internal pay scales in order to ensure that science and maths teachers are paid 5% more than they are currently. Schools that still have to work within the national pay bands should also be able to do this, assuming that their maths and science teachers are not already at the upper limit of their pay band. This will of course be challenging for schools without additional funding being provided by central government to help cover these costs. Indeed, an important distinction between the increased-recruitment and increased-retention strategies for tackling teacher shortages is that the costs of the former are born directly by the government, whereas the costs of the latter come out of school budgets. Assuming the government is committed to closing the teacher deficit however, making the extra money that's necessary to increase the salary of shortage-subject teachers available to schools will be cheaper than its current approach. Relying on schools to implement the policy requires schools to make a behavioural change. However, the most recent data we have suggests they are not yet doing this.

A more radical option would be for the government to pay the supplement directly to early-career, shortage-subject teachers. Indeed, the government is already planning to do this through its new policy of offering student loan forgiveness for science teachers. The Department for Education claim that this will be worth £540 a year in additional take-home pay for the typical teacher in their fifth year on the job. [35] The average gross salary for a fifth-year teacher in 2014 was £31,775 per year, making this equivalent to around 1.7% of gross annual pay. [36] The analysis presented in this paper suggests that, although a pay supplement of this magnitude would help reduce the deficit of teachers in these subjects, it will not be sufficient to eliminate it. The government is also planning to introduce early-career payments for maths teachers of at least £5,000 in their third and fifth years of continuous service. This is equivalent to 8% of the gross average earnings across the first five years of teaching in 2014. [37] The analysis presented in this paper suggests that this policy would have been sufficient to eliminate shortages had it been introduced in 2010. It will therefore likely go a long way towards eliminating current shortages if it is left in place for a sufficient length of time.

A common argument against giving salary supplements to teachers in some subjects is that it is unfair to pay two teachers a different amount for doing the same job. One way of responding to this argument is to point out that science and maths teachers are not doing the same job as other teachers. Teaching a core subject often brings with it extra pressure: English and maths count twice in Progress 8 and, starting from the 2017/18 academic year, all pupils will take double-award science. As discussed, many science teachers also have to teach three different subjects which imposes additional demands on them, particularly early in their careers. Another way of responding to this objection is to note that teachers are not paid the same for the doing the same job anyway. The national pay spine, under which pay increased uniformly with the number of years of service, was abolished in 2014. Moreover, because the policy only applies to new cohorts, introducing these changes in schools will be less controversial than if they were applied retrospectively to existing teachers. Only *new* teachers entering the profession would be paid more. Both the total pay and the pay ratios of existing shortage/non-shortage teachers would be unaffected.

In any case, this analysis makes clear the trade-off that we face. We can either have a small 5% pay gap between teachers of different subjects and eliminate the persistent shortage of science and maths teachers, or maintain the status quo around pay and continue to have a shortage of science and maths teachers. This is a debate which we need to have.

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