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Pennies from heaven

Using exogenous tax variation to identify effects of school resources on pupil achievement

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Abstract:
Despite important policy implications associated with the allocation of education resources, evidence on the effectiveness of school inputs remains inconclusive. In part, this is due to endogenous allocation; families sort themselves non-randomly into school districts and school districts allocate money based in order to compensate (or reinforce) differences in child abilities, which leaves estimates of school input effects likely to be biased. Using variation in education expenditures induced by the location of natural resources in Norway, we examine the effect of school resources on pupil outcomes. We find that higher school expenditures, triggered by higher revenues from local taxes on hydropower plants, have a significantly positive effect on pupil performance at age 16. The IV estimates contrast with the standard cross-sectional estimates that reveal no effects of extra resources.

Keywords: Pupil achievement, school resources

JEL classification: I21, I28, J24

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1. Introduction

Knowledge of the relationship between school resources and student achievement is crucial for policy design. However, despite decades of research, the literature in this area is still inconclusive.[1] In part, this is due to the difficulty of estimating the relationship between inputs and outputs due to the non-random allocation of resources. If parents who care more about education ensure that their children attend a "high resource" school, it may in fact be the parents who are causing the better performance and not the school itself. In a similar vein, if school districts allocate money based in order to compensate (or reinforce) differences in child abilities, simple OLS estimates of the relationship between money and performance will be biased.

Identification of the effects of school resources faces several obstacles. First, resources are typically endogenously allocated in response to pupil heterogeneity. Educational efficiency is characterized by an allocation with larger classes and lower teacher–pupil ratios when pupils are well behaved (Lazear, 2001). Moreover, when school authorities care about equality in outcomes, resources are partly allocated to schools on the basis of needs. Consequently, efficiency considerations and preferences for equality of outcomes may contribute to a negative association between pupil ability and school resources.[2] Second, school resources are multidimensional, and the "all other inputs equal" effect can be hard to identify. For example, the familiar cap on class size, like the Maimonides' rule, generates an exogenous variation in group size (Angrist and Lavy, 1999). However, teacher hour intensity per class is subject to choice, and school districts are likely to allocate more teacher hours or other resources to pupils who, for exogenous reasons, end up in large classes. Finally, mobile families may respond to school resource heterogeneity or sort themselves into school districts or municipalities for other reasons, such as the quality of housing (Hoxby, 2000).

This study aims to identify the effects of school inputs on pupil achievement at age 16 in Norway achievement using a rich dataset from Norway including residential histories of parents. Our approach exploits the location of a natural resource –waterfalls – and a set of institutional features for taxing this resource that generate *exogenous expenditure variation* across school districts. Teaching of children up to age 16 is provided at the municipality level in Norway. School spending is limited by budget constraints faced by local communities, and resource effects can in principle be identified by utilizing variation in the level of revenues, or priorities, across municipalities. Richer local communities spend more on schools, but local budgets are not orthogonal to the pupil composition.

[1] Leading scholars interpret the evidence differently; see Krueger (2003), Hanushek (2003) and Todd and Wolpin (2003).

[2] Woessmann and West (2006) find strong evidence of compensatory resource allocation across schools and within schools based on students' ability using international data.

Typically, children in high-income families tend to live in municipalities with high levels of tax revenues. To satisfy appropriate exclusion restrictions, we need a municipality-level revenue component that is "exogenous". Natural resources often provide economic resources that are unevenly distributed across regions. In Norway, hydropower plants provide a tax base for a group of municipalities, as nature (closeness to the waterfalls) and technology (introduced about 100 years ago) determine plant location and access to this immobile tax source. Nature determined the direction of the waterfall, technology determined the location of power plants and the parliament has given local municipalities discretion to impose a property tax. Unlike taxes on income, the property tax is not taken into account when redistribution among municipalities, including transfers from the central government, is determined. About 40% of the municipalities receive revenues from property tax on hydropower plants, and we show that most of them spend significantly more on education than other comparable municipalities. The effect of school resources is identified by means of instrumental variable techniques focusing on the extra spending, or alternatively, teacher hours, provided by the hydropower communities. We motivate the IV procedure by reporting non-parametric (Wald) estimates from matching on a large set of municipality-level variables relevant for school expenditures.

Because a single expenditure component such as class size is subject to input substitution bias, we focus on overall measures like teacher hours or total expenditures, both relative to the number of pupils. Variation in a single component such as class size, keeping all other factors equal, is rarely observed. Thus, identification by means of Maimonides' rule does not account for endogeneity of other inputs. When more input characteristics are available in the data, there is also a potential pitfall associated with "over-controlling" (Todd and Wolpin, 2003).

We use matched register data for a complete cohort of graduates from the final year of compulsory schooling (10^{th} grade, age 16), including information on schools and pupils' performance at a centrally marked exam. Conditioning on a rich set of family background variables, we are able to control for differences in pupil composition across municipalities. Because our instrument is given at the municipality level, we measure performance at the municipality level by means of estimated municipality fixed effects from an individual level regression, conditional on pupil and family characteristics. Given local government revenues, the level of school resources is influenced by the preferences of the electorate in the municipality and the local cost structure for operating schools, and we control for this variation by conditioning on a number of variables reflecting relevant municipality characteristics

The municipalities with hydropower tax revenues are typically small communities with scattered populations and longer travelling distances, and thereby not representative of the broader population in terms of community characteristics. In order to limit potential bias because of selectivity of municipalities, we focus on "comparable municipalities", defined as the subset that has a similar cost structure when it comes to running schools.

Our main findings are as follows. Standard least squares estimates indicate that school resources do not affect exam scores. When using hydropower tax revenues as an instrumental variable, school resources are found to have a significantly positive impact on pupil performance. The IV results indicate that NOK 10,000 (US$1,175) higher expenditures per pupil are estimated to raise the exam mark by 0.181. Thus, every sixth pupil will have his/her exam mark raised by one level, on a scale from one to six, if the municipality spends NOK 10,000 more on each of them in school. Furthermore, this positive resource effect seems to be mainly driven by the outcomes in municipalities with high levels of hydropower tax revenues and school expenditures.

We also test for alternative explanations of our findings. These robustness checks include testing for whether children are inherently different in these municipalities, selective mobility in and out of hydro power municipalities, and lastly whether other amenities, such as better day care facilities, in hydro power municipalities may explain better performance at the age of 16. We find no indication of superior initial endowments among kids born in these municipalities. Endogenous mobility is not driving our results: Estimates based on the majority of pupils born in the municipality of graduation do not differ from those which include pupils moved in after birth and results do not change when we allocate pupils to their municipality of birth rather than their municipality of graduation. Finally, the observed differences in the level of day care services (as an example of correlated amenities) are unlikely to explain performance differentials more than ten years later

2. Identification strategies and empirical specification

Using non-experimental or observational data to identify causal effects of school resources on student performance is challenging because school authorities, teachers and parents all make choices (Todd and Wolpin, 2003). School authorities not only fix total spending but also decide on the mix of input factors. If a single component is restricted, say class size, input substitution is likely to take place, for equity or efficiency reasons. Large classes are given more teacher hours, or extra resources of another kind. In addition, resources are usually allocated endogenously in response to pupil heterogeneity. Residential choice represents another challenge. Pupils are not randomly distributed across schools because families sort themselves into municipalities and school districts as a consequence of choosing a neighbourhood to live in. Finally, teachers may adjust their efforts in response to changes in school resource inputs. Consequently standard regression based evidence will only provide limited insight into the effect(s) of school resources on performance. The influence of sorting and input substitution on the correlation between the error term in the performance equation (unobserved ability and unobserved school inputs) and school resources is likely to differ across countries depending on the institutions that allocate resources to schools, and the pattern of parental school choice. While family sorting in the United States is likely to establish a positive association because families with stronger preference for education cluster in school districts with more resources, compensating resource allocations are presumably more important in (many European) countries with a more centralized public funding of schools. All in all, the presence of input substitution and compensating resource allocation imply that standard correlations between observed school inputs and pupil outcomes may not reflect causal relationships, even if they are conditional on a large set of relevant controls.

Several identification strategies are used in the literature. The *experimental approach* requires specifically designed data. Krueger (1999) and Krueger and Whitmore (2001) build on randomized allocation of resources to pupils—the Tennessee Student/Teacher Achievement Ratio (STAR) experiment conducted in the 1980s—to test the effect of *class size* on test scores. Their evidence supports the view that smaller classes improve test scores. The *natural experiment or quasi-experimental tradition* uses regular observational data, focussing on institutional features that provide exogenous assignment of different school environments to pupils. The influential study by Angrist and Lavy (1999) exploits the so-called Maimonides' rule, fixing the maximum class size in Israeli schools, so that class size is directly related to the number of pupils in a given grade. Their findings support the view that smaller classes raise test scores. A growing number of studies have followed in the Angrist/Lavy tradition using regression discontinuity design—also with certain extensions of the original model—to identify class size effects on test scores. Recent studies from France using variants of this identification strategy find that smaller classes have a positive effect on student performance at both primary and secondary levels, although the magnitude of the estimated effects varies (Piketty, 2004; Piketty and Valdenaire, 2006; Gary-Bobo and Hahjoub, 2006;). Among Nordic studies, Browning and Heinesen (2003) as well as Bingley, Myrup Jensen and Walker (2006) obtain the same result using Danish data. A recent study using Norwegian data in the Maimonides' rule tradition, Leuven, Oosterbeek and Rønning (2006), uses basically the same pupil data as this paper. They find no effects of class size on pupil performance at age 16. Also Bonesrønning (2003) exploits restrictions on maximum class size to estimate the effect of class size on pupil performance among Norwegian 9th graders. He finds generally weak effects of class size, and the effect varies strongly with pupils' family background as well as their effort. The maximum class size approach faces a problem of input substitution. School resources are multidimensional and not allocated in fixed proportions across schools. If restrictions apply to a subset of school inputs, and variations in restricted school inputs may be mitigated through substitution of other inputs, estimates based on exogenous variation in the restricted input may produce biased results. For example, assume a maximum class size of 30 pupils. In a school with 28 pupils in one grade and 32 in another, class sizes will be 28 and 16, respectively. To the extent that teacher intensity matters for pupil performance, and that school principals and authorities care about equity across grades, they will allocate extra teaching resources, and even their best teachers, to the larger classes. In this case, using class size as the resource variable and regulations on class size as an instrument is problematic, because the instrument will be correlated with the error term in the achievement equation. As shown in Hægeland, Raaum and Salvanes (2004), this argument is also empirically relevant, because there is a positive correlation between class size and teacher hours per class in Norwegian lower secondary schools. In addition, "class size" is outdated as a well-defined input component in education production. The technology of teaching has changed over the last 15 years, with larger variations in group size and teacher intensity per group across subjects (see Telhaug, 1991; Cuban, 1994). It is far from evident that the size of the class captures the relevant cost components important for student performance.[3] Consequently, teacher pupil ratios defined at the grade level represents a more relevant input measure, for methodological reasons as well as policy relevance.

Among other studies in the quasi-experimental tradition, Hoxby (2000) uses data from Connecticut in the US and relies on an experiment design in which cross-county variation in birth rates and rules that determine the minimum and maximum class size are used for identification. Hoxby concludes that the class size effect on pupil test scores is equal to zero. Hanushek, Rivkin and Taylor (1996) use US data at different levels of aggregation and estimate the effect of teacher–pupil ratios and teacher salaries on test scores and post-secondary education outcomes for high school students. They do not find any effect of school resources. Lindahl (2005) collected information for about 550 pupils from 16 schools in Stockholm during 1998 and 1999. The pupils took standardized tests in math at the end of the 5th grade, in the middle of the 6th grade and the end of the 6th grade. Using a value-added approach, he finds some support for pupils taught in small classes achieving better performance than those taught in large classes. Hakkinen, Kirjavainen and Uusitalo (2003) use Finnish data from the lower secondary level and estimate the effect of teacher expenditures on student test scores. The exogenous variation in municipality-level school spending caused by the dramatic recession in Finland in early 1990s is used as an identification strategy. They find no significant effects. Card and Krueger (1992) exploit a court ruling that caused randomized changes in school funding to determine the effect of school quality on the convergence of the black/white wage differential. They find reasonably strong

[3] In fact, regulations on maximum class size were abandoned in 2003 in Norway. Pupils are no longer connected to a fixed class at all times but to smaller or larger groups depending on the subject. During a typical school day, pupils are also grouped according to maturity or subject-specific competence. This practice has been common in the Nordic countries, even before the maximum class size regulations were abandoned.

effects of pupil/teacher ratios and teacher salaries on the black/white wage ratio. Card and Payne (2002) find that exogenous increases in funding of schools by state Supreme Court rulings improve tests scores in low-income areas compared with high-income areas.

Our approach exploits a particular feature of the Norwegian system for allocating resources across schools. Teaching of children up to age 16 and other local public services are provided at the municipality level.[4] Richer local communities spend more on schools. A substantial number of local communities receive "exogenous" revenues, providing independent variation that helps identify causal effects of school inputs. We argue that the property tax revenues from hydropower plants located in the municipality, *unlike other revenues*, represent an income source that is orthogonal to unobserved characteristics of the pupils (that affect school performance). More institutional details are provided in sections 3 and 4. To avoid the problems of partly unobserved input substitution, we focus on comprehensive measures of school resources such as total expenditures and teacher hours per pupil.

Because both schools and the property taxes on hydro power plants are administered by the municipalities, our analysis is naturally carried out at the municipality level. The institutional setup calls for a standard instrumental variable (IV) approach where the estimator is based on the following two equations.

$$(1) \qquad \textit{School resources}: \quad SR_m = a + bFAMCOMP_m + cMUNCTRL_m + dHPTR_m + u_m$$

$$(2) \qquad \textit{Pupil performance}: \quad A_m = e + g\, SR_m + f\,FAMCOMP_m + h\,MUNCTRL_m + v_m\,.$$

In the resources equation (1), we use teacher hours per pupil and total expenditures per pupil as the two alternative measures of SR_m, where m indicates that all variables are at the municipality level. In addition to the hydropower tax revenue ($HPTR_m$) used as the instrument, we include a number of municipality-level controls ($MUNCTRL_m$) such as the number of pupils and travelling distances (see section 4 for a detailed discussion and definitions). In addition, we control for an extensive set of family background variables (see section 3 for details), aggregated up to municipality level ($FAMCOMP_m$). In the outcome equation (2), our estimate of pupil performance is affected by SR_m instrumented by $HPTR_m$, conditional on all the other variables in the school resources equation.

The parameter of interest is g. The need for an instrument arises from the potential interdependence between u_m and υ_m. Sorting on unobserved pupil ability as well as compensating

[4] However, curriculum and teacher certification criteria are set at the national level.

resource allocation will generally create a correlation between these two residuals. If we estimate the outcome equation directly, a bias is likely to arise because of the correlation between school resource use (SR_m) and the residual, υ_m.

Because we are estimating the equation at the municipality level, we construct an adjusted municipality performance index (A_m). We estimate this municipality level outcome variable as the municipality fixed effect (α_m) in a cross-section regression of individual performance (Λ_{im}), on gender, age, exam subject, all variables captured by C_i and a detailed set of family background characteristics (F_i). The equation is expressed as follows:

(3) $$\Lambda_{im} = \sum_{m=1}^{M} \alpha_m M_{im} + \gamma C_i + \beta F_i + \varepsilon_{im},$$

where i denotes the individual, and $M_{im} = 1$ if pupil i graduated in municipality m, zero otherwise. Thus, $A_m = \hat{\alpha}_m$. In order to take into account the grouping of pupils into municipalities and the use of estimated coefficients in (2), we utilize the FGLS estimation procedure described in Hanushek, Rivkin and Taylor. (1996).[5]

Norwegian municipalities are quite diverse along several dimensions. In our analysis, we focus on a subset of "comparable" municipalities with a similar school cost structure and exclude municipalities with a set of characteristics that predict particularly high or low expenditures (see section 4 for details). To complement the IV analysis, we also report estimates from a more flexible approach where the performance of pupils in communities with hydropower tax revenues is compared directly with outcomes of pupils in "neighbouring" municipalities. Neighbours are not defined by geographical closeness but by predicted school expenditures. This Wald estimator simply relates the performance differential and the observed resource differential, and the effect is defined as the ratio between the two.

Even with "exogenous" school resource allocation along the lines just described, problems related to mobility remain. Families and pupils move, and they sometimes cross municipality borders. The first problem related to mobility is that of endogenous location. Pupils tend to cluster non-randomly in schools because *parents* sort themselves into neighbourhoods and school districts. If these processes sort pupils with (dis)advantaged backgrounds into districts where schools have (low) high resource use, the effect of school resources on pupil achievement is upward biased.

[5] The estimation procedure is as follows: (1) and (2) are first estimated by ordinary two-stage least squares. The square of the residuals from (2) are then regressed on the sampling variance of the municipality fixed effects, $\hat{\alpha}_m$, from (3). The inverses of the predicted squares of the residuals from this regression are used as weights in the two-stage feasible generalized least squares estimation of (1) and (2).

Peer effects, where pupils benefit from having clever schoolmates, are likely to reinforce this. Both effects may be empirically relevant in our setting, because it is public information that municipalities with hydropower plants tend to spend more on, and presumably offer a higher quality of, local public goods such as schools. Conditioning on a very rich set of family characteristics partly solves the problem, but there may still be biases because of unobserved ability. It is not obvious, however, that families with high-ability children are the most likely to locate in municipalities with *HPTR*. On the one hand, parents with children who (are expected to) need special attention or supervision, might have extra incentives to move into a community with extra resources. On the other hand, education-oriented parents are more likely to move into high-resource areas. Consequently, sorting on unobserved variables may affect the estimate, but there is no obvious direction of the potential bias.

The second problem is related to the "exposure period" and adequate measures of resources. Pupils accumulate skills over time, and their performance at age 16 will typically reflect school input throughout their whole career, not only the resources experienced during the final three years as observed in our data (see Todd and Wolpin, 2003). As a consequence of mobility among pupils during their school age, the effects of school resources tend to be downward biased because of measurement error. Moving pupils have been exposed to resources different from those observed at the time of graduation.

Our main analysis does not address the problem of endogenous location explicitly. However, detailed information on the municipality of residence and migration patterns of pupils and parents across municipalities over a long period of time enables us to study mobility patterns and "test" implications of mobility by estimating school resource effects, conditional on seniority in the municipality of graduation. More specifically, we estimate the effect of school resources, conditional on graduation in the municipality of birth, and also on whether the mother lived in the graduation municipality in 1980, seven years *before* the child was born.

Another aspect that our approach does not control for is that municipalities may allocate resources in a compensatory way across schools *within* the municipality. This is because our exogenous variation for identifying resource use is at the municipality level and not at the school level. Less resources are allocated to schools with pupils who are expected to perform well (for a given school environment), and more teacher hours are provided for schools with less "able" children. Compensating resource allocation implies that a pupil characteristic that has a positive effect on achievement also has a negative effect on resource variables and will bias estimates downward if the actual characteristic is not controlled for. It is important to note, however, that within municipalities, compensating resource allocation will only bias our results in so far as the resource effects vary across the ability distribution.

3. Data and institutional features

School districts

Norwegian municipalities operate schools to provide compulsory education (1^{st}–10^{th} grades, ages 6–16). They also provide basic health services, organized care for children and the elderly, and infrastructure like water and sewage, and they support a variety of cultural activities. Compulsory schooling accounts for, on average, about 29% of their total expenditures.[6] Municipal activities are financed by a local income tax, a "poll tax" in terms of housing-related utility charges, and property taxes, as well as redistributive transfers from the central government (see Borge and Rattsø, 2004). In addition to the local income tax with a capped rate, municipalities are allowed to impose a property tax, which accounts for a maximum of 0.7% of their tax base. About one-half of the municipalities currently have a property tax, and nearly all of these apply the maximum rate. Houses in "town-like" areas as well as physical capital of firms (buildings, machinery etc) may be taxed. Many municipalities choose to exclude houses from the property tax, in order to reduce the tax burden on their own residents. The municipality is free to implement a property tax on production facilities/plants, including hydropower plants. This property tax applies to all businesses, but the tax base (asset value) may be set low to avoid large taxes on locally owned firms.

School resources

We consider two alternative measures of school resources. Both are constructed as averages across schools at the municipality level, covering the three years prior to graduation to reflect school inputs during the period when the pupil attended lower secondary school.

Teacher hours. Every school provides annual information on (i) the number of pupils by grade and (ii) the total hours of instruction for 8^{th}–10^{th} grades to the Norwegian Compulsory School Information System (GSI). Traditionally, instruction has taken place within classes, but the number of teachers occupied with pupils belonging to a given class varies across subjects, classes, grades and schools.

Expenditures. Municipalities annually report expenditures by sector of activity to Statistics Norway. We use total expenditure on primary and lower secondary schools (1^{st}–10^{th} grades, ages 6–16) per pupil, excluding transport of pupils and costs associated with after-school, non-curricular activities ("SFO"). This expenditure measure covers wage costs for teachers and other

[6] Statistics Norway: Net expenditures primary and lower secondary education, as percentage of all net expenditures, average all municipalities (Statistikkbanken: netto driftsutgifter grunnskole i prosent av samlete nettoutgifter, 2005, gjennomsnitt alle kommuner.)

personnel, cleaning services, heating and lightning, teaching equipment, ICT, library services and maintenance of buildings. Norway spends more on primary and secondary schools than most other OECD countries. The cumulative expenditures on educational institutions per student over the duration of primary and lower secondary education exceed US$80,000 (in 2003 prices), which is very close to what is spent in the United States. Among OECD countries, only Luxembourg spends more (see OECD, 2006).

Pupil achievement at age 16

Our sample covers all pupils who completed compulsory education in Norway (10th grade in the lower secondary school) in 2003. Individual marks by subject, individual characteristics and family background variables are collected from administrative registers. In principle there is no attrition, but a small minority of pupils are dropped from the dataset because of missing family information. Data are collected by the Directorate for Primary and Secondary Education and contain information on which school the individual graduated from, as well as marks by subject. Marks are awarded on a scale from one to six (higher marks indicating better performance). This study focuses on performance in the final written examination at the end of 10th grade. The exam mark is based on a five-hour test in one of the core subjects of Mathematics, Norwegian or English. All pupils in the country do the same (subject-specific) test. Pupils are randomly allocated to subjects, and the marking is anonymous and done by external examiners.

Pupil characteristics and their family background

To measure C_i and F_i in equation (3), detailed information on pupil and family characteristics along a number of dimensions are taken from several administrative registers. All variables are constructed for the year in which the pupil graduates.

Demographic information and family structure: We include dummy variables for the pupil's gender, quarter of birth (given graduation in the year they turn 16) and graduation in years earlier or later than expected according to their age. Parents' marital status is measured by means of dummies reflecting whether they are married (to each other), cohabitants, separated, divorced or none of these, and dummy variables indicating whether the father and/or mother is unknown. The age of the mother and father at the birth of their first child is represented by dummy variables reflecting age intervals. Another detailed set of dummies reflects the number of full siblings, the number of half siblings and the rank in the birth order (of full siblings).

Parents' education: Educational attainment is classified into four categories: lower secondary, upper secondary, lower tertiary and higher tertiary education. Based on this classification, we construct dummy variables for all combinations of father's and mother's education.

Immigrant status: Pupils with both parents born abroad are classified as immigrants. We distinguish between 15 countries/regions of origin by means of dummy variables. Age at immigration *for the pupil* is defined by intervals distinguishing between those who were born in Norway or who immigrated before they were three years old, and those who immigrated when they were 3–5, 5–7, 7–9, 9–11, 11–13 or 13 years or more.

Economic resources, unemployment, disability pension and social assistance: As the permanent economic resources of the family may be more important than current income during the final school years, family income is defined as the sum of the father's and mother's taxable labour income during the last 10 years (regardless of marital status). Dummy variables reflect the position (quintile) in the family income distribution.

Family wealth for the pupil is defined as the sum of the father's and mother's individual taxable wealth for the year prior to graduation. Because wealth typically increases over the working part of the life cycle, we construct age-specific wealth distributions, where we divide families into five-year age intervals based on the average age of the parents. Dummy variables reflect whether the family belongs to one of the upper four deciles of its age-specific wealth distribution. (A majority of families have negative taxable wealth. The tax value of housing, which is the most common non-financial asset, is far below market value. Negative taxable wealth is reported as zero.)

Unemployment records are used to construct variables for the incidence of unemployment for the parents during the 10 years prior to the pupil's graduation. We ignore short unemployment spells and define a person as unemployed if he or she was registered as unemployed for at least three months of a calendar year. We construct dummy variables, separately for mother and father, for unemployment in the graduation year, and for unemployment one, two, three, four and five or more years during the 10-year period prior to graduation. Similarly, we construct variables indicating the receipt of a disability pension and social assistance. We define a person as on a disability pension if he or she received disability pensions for more than six months of the calendar year. Our criterion for defining a person as receiving social assistance is that he or she received at least NOK 20,000 (approx US$2,850) in a given year. Dummy variables for disability pensions and social assistance are constructed in the same manner as for unemployment.

4. Instrumenting school resources

Our identification strategy rests on the idea that richer local communities spend more on schools, see Aaberge and Langørgen (2003) for Norwegian evidence. Revenue variation across municipalities is partly generated by differences in what municipalities receive as income tax from their residents. Consequently, local government revenues are presumably not orthogonal to pupil composition. For example, children of high-income families tend to live in affluent local communities with high levels of tax revenues. Although the Norwegian state transfer system is highly redistributive, as higher local income taxes trigger reduced transfers from the central government, municipality revenues may be correlated with the ability of pupils.[7] To satisfy appropriate exclusion restrictions, we need an "exogenous" component of municipality tax revenues. In the Norwegian case, location of hydropower plants in combination with a local property tax constitutes a promising candidate because, basically, nature and available technology determine the location of hydropower plants and thereby the access to an immobile tax source. Hydropower technology was introduced about 100 years ago, and many of the power plants were established around that time. This timing of events therefore avoids the potential connection between location of plants and pupil ability that could exist if entrepreneurial people, with clever children, clustered in areas with power plant investments.[8]

Local property taxes from hydropower plants

Information on local government revenues generated by tax on hydropower plants (*HPTR)* is not readily available, but we have collected data specifically for this study. Only total yearly property tax revenues are reported by the municipalities to Statistics Norway. By means of information on the property values for the around 800 hydropower "plants" (including dams and reservoirs) and detailed information on their locations (needed because a single "plant" can have facilities in more than 10 municipalities)[9], we calculate the share of the total property tax in 2002 that can be attributed to hydropower plants. Unlike taxes on other properties, these are typically paid by companies with owners outside the local community. Therefore, nearly all municipalities with waterfalls have implemented the maximum tax of 0.7% of the asset value of the hydropower facilities. Because a single hydropower plant often has reservoirs in more than one municipality, the asset value of each

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[7] See, for instance, Aaberge and Langørgen (2003) for an assessment of the degree of redistribution across municipalities in the Norwegian tax system.

[8] One could argue that intergenerational transfer of skills would imply that descendents of the entrepreneurs are a selected group of pupils, but the relatively low earnings persistence across generations in Norway (see Bratsberg *et al.*, 2007) suggest than any such sorting effect would be negligible within a two- or three-generation perspective.

[9] The tax base, or property value, is determined by the net present value of the plant's revenues and costs. In 2002, however, the value of all plants was subject to a minimum value, proportional to the average production during the previous five years.

plant (tax base) is distributed across local governments according to percentages determined by The Norwegian Water Resources and Energy Directorate (NVE).

We calculate the share of property taxes related to hydropower plants in 2002, and we multiply this by yearly total property taxes to get an estimate of the average annual hydropower property tax during 1992–2000, by municipality. We deliberately use the permanent level of *HPTR* because local authorities are expected to smooth consumption. Local politicians are unlikely to adjust school spending to transitory shocks in *HPTR*.[10]

Determination of school resources

To provide information about the scaling of variables, Table 1 describes the distribution of resources across municipalities, based on all municipalities with valid information on all variables. On average, expenditures per pupil are around NOK 54,250 (US$7,800). The variation is substantial, as the 10th percentile spends NOK 43,900 (US$6,300) and the 90th percentile spends NOK 68,600 (US$9,800). For comparison, Hanushek, Rivkin and Taylor (1996) report that expenditures across US states in the early 1990s varied between US$2,960 and US$8,645. Among municipalities without hydropower revenues, average expenditures are lower. The variation in teacher hours across all municipalities is also substantial with a 90–10 log-differential of about 0.62. As for total expenditures, teacher hours per pupil are lower in municipalities without *HPTR*.

The coefficients of the school resource regressions are displayed in Table 1, Panel B. The first two columns show how *HPTR* influences the level of resources, conditional on other municipality characteristics. The effect of hydropower tax revenues on expenditures is significantly positive, with a t-value of about seven. The point estimate is close to unity: If hydropower tax revenues *per capita* increase by one NOK, expenditures *per pupil* increase by NOK 0.89. The effect on log teacher hours per pupil is estimated to be 0.065, which says that an extra NOK 10,000 in hydropower tax revenues per capita raises teacher hours by about 6.5%. However, the t-value is just above two, indicating that *HPTR* is a weaker instrument for teacher hours per pupil.

Given local government revenues, the level of school resources is influenced by preferences of the electorate in the municipality and the local cost structure for operating schools. Panel B includes estimates of cost-related expenditure determinants like the number of pupils, travelling distances measured by average travelling minutes from the centre of own neighbourhood to the next (“neighbour”) and to the municipality centre (“zone”), as well as the proportion of disabled children. Expenditures related to schools are fundamentally linked to the size of the school-age

[10] For the same reason, the difference-in-difference IV approach exploiting changes in *HPTR* within municipalities using multiple pupil cohorts is inadequate.

population. This is particularly so in communities with a scattered population, as limits on acceptable commuting distances generate sizeable economies of scale. Expenditures per pupil are, for small and medium sized municipalities, decreasing in the number of pupils. Locations of houses, and thereby the travelling distances of pupils, affect costs via the number of schools. Longer distances cause expenditures and teacher hours to rise. Disabled children are typically integrated in local schools with additional resources. To account for the presence of pupils requiring extra resources, we include the share of mentally disabled pupils aged 6–16, as well as a number of family background characteristics of the graduating pupils; the shares of parents with tertiary education and upper secondary school, as well as the shares who are unemployed, receiving welfare transfers or disability pension, and the share of non-western immigrants as defined in section 3.[11]

The family background of the actual pupils affects the resources through compensating resource allocation. When pupils have a more privileged family background, fewer resources are allocated to schools. The positive signs on unemployment are clear evidence of this practice, and the negative effects of higher parental education point in the same direction. The results for family earnings, i.e., the fractions in the lower and upper quintiles, are mixed, but the high correlation between family characteristics makes it hard to get precise estimates of each of them.[12]

The priorities of the local council and its constituency seem to affect school resources. A politically left local majority and a more educated electorate (share of the adult population with higher education) have a positive influence on school resources, but the coefficients are not always significant.

Comparable and neighbouring municipalities

The municipalities with hydropower tax revenues are not representative in terms of community characteristics. They are typically small communities with scattered populations and longer travelling distances. This heterogeneity may generate correlations between expenditure determinants, hydropower tax revenues and unobserved factors affecting pupil performance. In order to limit potential bias because of selectivity of *HPTR* municipalities, we focus mainly on "comparable municipalities" defined as the subset that holds a similar level of predicted expenditures. We define comparable municipalities as those who hold predicted expenditures (teacher hours) within the range

[11] We do not simultaneously model the municipality supply of different services. For example, via the budget constraint, changes in the elderly population that generate an increased level of services in care for the elderly may affect resources allocated to schools (Aaberge and Langørgen, 2003). Actually, we have included variables that affect other types of municipality expenditures, like the age distribution of the population, but they do not seem to have any effect on school spending.

[12] If we use the average predicted individual performance of the pupils based on micro level family characteristics, instead of aggregated family characteristics, we get a significant negative estimate clearly supporting the existence of compensating resource allocation.

observed among municipalities with and without *HPTR*. To predict school resources we use estimates from the sample of municipalities without hydropower tax revenues (column (2) in Table 1).

In Figures 1 and 2, we first compare municipalities with *HPTR* (Panel A) and without *HPTR* (Panel B) and display the kernel densities of the predicted level of expenditures and teacher hours, respectively. The comparable communities for expenditures lie in the range of NOK 45,000 to 78,000 per pupil and for log teacher hours between 4.30 and 5.09. As will be clear below, our main effects will partly be driven by outcomes in municipalities with high *HPTR*. The C panels display the distributions in these communities. Basically we exclude municipalities with extremely low and, to some extent, high levels of *predicted resources* per pupil, illustrated by the vertical cut-off lines in Figures 1 and 2. Municipalities with low costs typically have more pupils than the largest among those with hydropower tax revenues.

Considering the set of comparable municipalities, Table 2 displays the means of municipality characteristics, by level of hydropower tax revenues. We have already shown that municipalities with positive *HPTR* use more resources, and the numbers are displayed in the first two rows. However, low levels of *HPTR* appear to have no effect on school resources.

Municipalities with *HPTR* are also different from other municipalities along a number of other dimensions. They are smaller in terms of average number of pupils, and travelling distances are somewhat longer. *HPTR* municipalities are more likely to have a politically left majority, but the fraction of voters with tertiary education is of a similar magnitude. There is no systematic difference according to the observed family background of the pupils. As *HPTR* is determined by nature (topography), a possible concern is that *HPTR* serves as a proxy for geographical location and hence reflects regional effects that may affect resources and (unobserved) pupil ability. Figure 3 illustrates that municipalities with *HPTR* are widely scattered across the country although many are located in the central, high-altitude areas of the southern part of Norway.

Returning to the power of the instrument, we find that the effects of *HPTR* on resource use are slightly lower when we restrict the analysis to municipalities with a comparable expenditure structure (see column (3) (*comparable municipalities*) in Table 1, which are the first-stage regressions in our IV analysis). However, even across comparable municipalities, *HPTR* is a powerful instrument for school spending. Figure 4 displays the relationship between *HPTR* and residual expenditures (left) and teacher hours (right). (Residual expenditures are defined as the difference between observed and predicted expenditures based on parameters in column (3) of Table 1.) In other words, the two figures display the effects of the instrument, conditional on municipality characteristics that affect variation in cost structure and priorities. Basically, the figures indicate that, first, the effects of the instrument are not totally driven by extremely rich municipalities and, second, linearity seems to be a fairly good approximation. We see that there is a larger effect of *HPTR* on expenditures per pupil than on teacher hours per pupil. Thus, *HPTR* is a stronger instrument for the former resource measure. For teacher hours, there are also some outliers with high *HPTR*, but excluding these municipalities does not qualitatively affect our findings.

Our Wald estimator in section 5 is based on a comparison of pupil performance in municipalities *with and without HPTR*. In order to make the Wald estimates as comparable as possible to the regression results, we make the two groups as equal as possible by matching municipalities. The matching procedure follows the "nearest neighbours" principle, where neighbourhood is determined by cost structure, not by geographical location. The idea is that differences in resource use between two municipalities that are similar according to the factors that determine the costs of providing schooling at a given standard can be used for comparing pupil outcomes. The matching approach compares two sets of municipalities, where one is "rich" because of *HPTR* and the other is less affluent (within each pair). The hydropower tax revenues imply that more resources are allocated to schools in the richer communities. Based on the school resource models in column (2) of Table 1, we calculate predicted school resources, given observed municipality characteristics, and we select for each *HPTR* municipality its five closest neighbours. We have chosen to include more than one neighbour to reduce the variance in both resources and performance. The disadvantage of including more neighbours (i.e., less precise matches are therefore a potential bias) is limited because the differences in predicted resources between potential neighbours are fairly small.

In Tables 3A and 3B, Panel A, we report the level of school resources in the municipalities with *HPTR* and their neighbours. Municipalities with low *HPTR* have higher expenditures on schools than their neighbours (see Table 3A), but their teacher/pupil ratios are almost identical (see Table 3B). When *HPTR* is substantial, municipalities spend more on schools and have more teachers than their neighbours. The B panels of both tables display the mean characteristics of the *HPTR* municipalities and their neighbours. *HPTR* municipalities are typically smaller and tend to have longer travelling distances. Other municipality characteristics are fairly similar, but there is a tendency for *HPTR* municipalities to have characteristics that contribute to lower spending, counteracting the effects of size and travel distances.

5. School resource effects

We start the presentation of the results first by showing performance differentials for neighbouring (matched) municipalities. The logic of our identification strategy builds on the idea that effects are defined by different, and presumably superior, performance among students in *HPTR* municipalities.

Column (1) in Table 4 displays the performance differentials, measured by average exam marks, the proportion with “basic skills” (mark above 2) and the proportion with high skills (mark 5 or 6). These differentials are adjusted for family background characteristics as discussed in section 2, i.e., $A_m = \hat{\alpha}_m$ from estimation of (3). When we compare all *HPTR* municipalities with their matched neighbours, the differential in average marks is .032, and an equal percentage obtains basic skills (.007 differential in Panel II), while more pupils get the highest scores (.019 differential in Panel III) in *HPTR* municipalities. Except for the proportion of pupils with high skills, the differentials are not significant. It is evident from rows 2 to 4 in Panels I–III that the positive performance differentials are larger for municipalities with high levels of *HPTR*, for which even the mean differential is clearly significant.

Columns (2) and (3) in Table 4 provide the Wald estimates, which relate the average outcome differentials in column (1) to the respective resource differentials by simply calculating the ratio between the two. We see the Wald statistics based on these differentials as preliminaries, or advanced descriptive statistics. Considering all *HPTR* municipalities, the effect on average performance is positive for both teacher hours and expenditures, but the latter is not statistically significant. A 10% increase in teacher hours per pupil is estimated to raise marks by .044, which amounts to a one level improvement for one in every 25 pupils.

At the lower end of the achievement distribution, the Wald estimator suggests a small and positive effect on basic skills (Panel II) from increased teacher hours, but again only significant at the 10% level. Higher expenditures do not seem to have any effect on basic skills when we compare (all) municipalities with and without *HPTR*. The impact on the proportion with high skills is larger and significant (Panel III), with estimates equal to .041 and .018 for expenditures and teacher hours, respectively.

The positive effects of school resources seem to be driven mainly by the outcomes of high-*HPTR* municipalities. When we split by level of *HPTR*, no significant effects are found based on municipalities with low or moderate *HPTR*. Pupils in municipalities with high *HPTR*, however, have significantly better performance than pupils in neighbouring communities. The Wald estimates are all significant, except for basic skills. All in all, the Wald estimates of Table 4 clearly suggest that (large) differences in school resources do matter.

Turning now to our preferred IV approach, the main results are given in Table 5. Column (1) reports the bivariate least squares regression coefficients and reveals that school resources are basically uncorrelated with measures of pupil performance in comparable municipalities. However, if compensating resource allocation to improve achievement among low-ability pupils is important, the effects of school resources are biased downwards unless we control for pupil composition. When we condition according to individual family background, we do find significantly positive effects of expenditures as well as teacher hours (see column (2) in Table 5). This pattern is consistent with an allocation of resources where more needy pupils attract extra money to schools.

The IV estimates are reported in column (4). More resources in terms of higher expenditures do have a significantly positive effect on pupil performance. Additional expenditure of NOK 10,000 per pupil is estimated to raise average marks by .181. Thus, every fifth or sixth pupil will have his/her exam mark raised by one level if the municipality spends NOK 10,000 more annually on each of them in school. An extra 10% in teacher hours per pupil raises the average mark by about .252, i.e., a one-level rise for one in every four pupils (see column (4) in Panel B). It should be noted, however, that the precision of these estimates is not impressive. Standard errors are one-third to one-half of the estimated coefficients, indicating that the lower bounds of the confidence intervals are close to zero.

When we look at the resource effects across the performance distribution (see rows II and III in Table 5), our estimates suggest that the effects are larger among the more able pupils. For expenditures, IV estimates are significant at the 5% level for both basic skills and high skills, but the estimate is larger for the latter. The effects of teacher hours are less precisely estimated and only significant at the 10% level.

Compared with all OLS estimates with municipality controls in Table 5, IV estimates are substantially higher. This suggests that compensating resource allocation is important in Norway and contributes to a significant downward bias in the standard cross-sectional estimates of school input effects.

6. Robustness checks

The main results are based on comparable municipalities with a similar set of characteristics. Even if we prefer this restriction, it is not crucial for our conclusions. The results based on all municipalities are reported in Table 6, and they turn out to be very similar. While point estimates are slightly lower, the effects are of the same order of magnitude, and they remain significant.

Our identification is based on cross-sectional variation across municipalities and even if we condition on a large number of family characteristics, and there are several potential issues related to how robust our results are. First, the pupils in the municipalities with hydro power incomes may be *inherently* different in terms of endowment before starting school conditional on the rich set of parental characteristics . Second, selective mobility in and out of hydro power municipalities may affect the results. And third, other amenities like better day care facilities etc and not better schools in HPTR municipalities, may contribute to explain the superior school performance at the age of 16. In this section, we look empirically at the implications of these alternative explanations, and conclude that the results are hardly affected in any substantial way.

Are pupils inherently different in hydro power municipalities?

The first issue is whether pupils are inherently different in hydro and non-hydro municipalities. Unobserved ability differentials correlate positively with *HPTR*. Over generations, geographical mobility and intergenerational transmission of skills may sort high-ability families and children into communities with *HPTR*. In technical terms, if positive sorting on unobserved characteristics is important, the exclusion restriction is invalid and the resource effect estimates would be upward biased. If early test score information were available, a straight forward test would be to inspect the correlation between the conditional municipality level means (or fixed effects) with the level of *HPTR*. Such measures are not available, but a companion data set contains initial endowment proxies that enable us to check this kind of associations.[13] In recent years, several studies have shown that an early child endowment measures such as birth weight, head size and apgar scores are fairly strong predictors for both early and later outcomes like educational attainment and earnings (Behrman and Rosenzweig, 2004; Almon, Chay and Lee, 2005; Black, Devereux and Salvanes, 2007). Table 7 displays the last squares regression coefficient on *HPTR* where the conditional average endowment indicator for each municipality is regressed against *HPTR* and the same municipality controls as in the main (IV) analysis. We find no association whatsoever for birth weight or head size, while the negative 'effect' of *HPTR* on the apgar-5 score suggests downward bias in our resource effect estimates rather than the opposite. In addition, the lack of systematic family characteristic differentials by level of *HPTR*, see Table 2, fits into this and provide evidence that supports our exclusion restriction.

Selective mobility

The second set of robustness checks is related to parental mobility between municipalities. Mobility may affect our estimates through various mechanisms. The first channel relates to the period of exposure to a resource regime. Because pupils who have moved experienced resources different from that observed at graduation, mobility among pupils may bias resource estimates downward because of measurement error. Second, selective migration is potentially important. In our context, families with certain characteristics may be more inclined to stay in—or move into—communities with high *HPTR* and school resources..

First, we track the residential municipality of pupils until graduation. About 83% of the pupils have lived in their graduation municipality throughout all 10 years of school (see Table 8). Because resources are fairly constant within municipalities over time, this high persistence suggests that the bias arising from measurement error is modest. We find a weak tendency for pupil seniority in the graduation municipality to be higher in municipalities with positive *HPTR* (see the last column of Table 8). There are also a slightly higher proportion of mothers in *HPTR* municipalities who lived in the same municipality in 1980, i.e., six years before the pupil was born. However, we do not expect that a minor difference of this magnitude will have any sizeable impact on our estimates.

The effects of mobility are examined in Table 9. Even if our real concern is about sorting on unobserved characteristics, a study of how observable family characteristics are associated with geographical movements is clearly indicative. If pupils of advantaged families tend to move into municipalities with (large) *HPTR*, there is reason to be concerned that our estimates are driven by systematic sorting. The estimates in Table 9 show the effects of family background, summarized by predicted marks using our large set of family background controls, on the probability of graduation in a municipality with high (columns (1) and (2)) and medium *HPTR* (columns (3) and (4)). Conditional on residence at ages 1–2, the tables report the effects of predicted marks (based on the complete set of family characteristics) on graduation in high- or medium-level municipalities. Estimates for all pupils (Panel A) and the subsamples of those who actually moved (Panel B) are reported. Because our results

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[13] The Norwegian birth registry contains information on a set of initial health indicators for all children in Norway from 1967-2006. See Black, Devereux and Salvanes (2007) for a detailed description of the data set.

are largely driven by the superior performance of pupils in municipalities with high *HPTR*, the main concern is mobility in and out of these communities. First, there is no indication that pupils born in regions without *HPTR* with favourable family characteristics are more likely to move to municipalities with high *HPTR*. On the contrary, higher predicted marks reduce this probability. There is, however, a tendency that pupils born in municipalities with positive *HPTR* are more likely to graduate in a municipality with high *HPTR* if they have a favourable family background. This largely reflects the low mobility of families in *HPTR* municipalities. Among pupils who actually move (see Panel B), there is no indication of a positive sorting on observables into high- or medium-*HPTR* communities. The estimated effects of predicted marks on graduation in high- or medium-*HPTR* municipalities are all negative. All in all, the relationships between family characteristics and mobility do not indicate that our resource effect estimates are upward biased. On the contrary, it there is any bias associated with family movements throughout the school years, they probably disguise some of the favourable effects of large school inputs.

As a further check on the impact of mobility we report estimates of the school resource effects, conditional on seniority in the municipality of graduation. Column (1) in Table 10A displays the effects of expenditures, based on non-immigrant pupils. They turn out to be almost identical to our main results in Tables 4 and 5. When we restrict the analyses to pupils born in their graduation municipality in column (2), the estimates are again very similar. For any given difference in the estimates, the effects of higher spending identified by the Wald or IV estimators are even larger. This is consistent with an explanation where mobility causes a bias because of differences in observed resources and what pupils have been exposed to throughout their school years. One might argue that families select themselves into municipalities according to parental preferences for children's education *before* the pupil is actually born. Estimates in column (3) are based on children of mothers living in the graduation municipality six to seven years prior to the time of birth. The precision of the estimates are lowered because of smaller samples and some of the effects are no longer significant. The IV estimate of expenditures on mean performance is somewhat lower (from .184 to .149), but still significant at the 10% level.

Table 10B displays the estimates from the same sampling exercise using teacher hours as the measure of school input. The pattern is similar for what is shown for total expenditures, but the precision is even lower presumably because our instrument is weaker for teacher hours than for total school expenditures.

One could argue that even the sub-sample of stayers is selective, as the out-migration from *HPTR* communities can be (negatively) correlated with pre-school ability of the kids. In the final columns of Table 10A,B we ignore the change in resources which is due to post-birth family mobility by allocating each pupil to his/her municipality of *birth* rather than to the municipality of *graduation*. The two coincide for about two thirds of the sample, see Table 8. We would expect a lower effect of school resources simply because measurement error is introduced for a substantial fraction of the pupils. If selective movers really explained our results, the estimated resource effects should go to zero. This is not confirmed. Columns (4) in Table 10A,B show that resource effects are slightly lower as we would expect from measurement error, but the IV estimates remain statistically significant.

Other amenities in hydro power municipalities

Finally, one might wonder whether other amenities in the *HTPR* communities actually can explain the superior school performance at age 16. They are rich municipalities with a wide range of high quality services like libraries, sport fields and public day cares. Empirical studies suggest that early education and high quality child care services have favourable long-term effects on development and educational attainment, but the evidence is mixed and hard to establish due to obvious selection issues (Currie, 2001).[14] Using an additional data set on the coverage of day cares by municipality, year and children's preschool age, we find that the coverage of day care for children aged 1-6 was about 50 per cent on average for the years relevant for our sample (1988-1993), with a substantially higher coverage in municipalities with *HPTR*.[15] Controlling for municipality characteristics (used to explain school resources in 'stage 1'), we find that an increase in *HPTR* with 1,000 NOK is associated with a 1.2 percent higher day care services coverage. A back of the envelope calculation suggests than a *HPTR* increase of 10,000 NOK would imply that one extra in nine pupils would have spent their pre-school years in a nursery. If the superior performance of pupils exposed to the increase in school resources triggered by 10,000 NOK more in *HPTR* actually was (totally) explained by this, nursery attendance (rather than spending time home with their mother, typically) would have to raise the expected mark at age 16 by 1.5(!), which is about two standard deviations. Cleary, the difference in child care coverage may explain just a minor fraction of the superior school performance at age 16 for pupils in *HPTR* communities. As a final check, we included child care service coverage as a municipality control in both stages of our IV estimation. Naturally, the power of the HPTR instrument drops a little, but the point estimates of the resource effects are basically unchanged while standard errors of the estimates increase a little.

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[14] We are not aware of any reliable evidence for Norway.

[15] This is a data set collected by Statistics Norway for the number of children in day cares, and coverage is calculated by using the population registry for Norway; see Løken and Salvanes (2007).

7. Conclusions

Unobserved pupil heterogeneity and incomplete measures of school inputs make empirical identification of school resource effects a challenge. Our approach is founded on a set of institutional features in the educational sector in Norway that generate exogenous variation in school resources, caused by differences in municipality level revenues orthogonal to pupil ability. Hydropower plants provide a tax base, as nature (closeness to the waterfalls) and technology introduced about 100 years ago determine their location and the access to an immobile tax source for a group of municipalities. In principle, we compare pupil performance in neighbouring municipalities that differ only in terms of power plant presence. In addition, we are able to control for a rich set of observable family background variables and factors that affect school expenditures. We examine the effect of school resources on student performance at the age of 16 using comprehensive resource measures—teacher hours per pupil and total expenditures in schools—to avoid input substitution effects. We find that more resources in terms of higher expenditures do have a significantly positive effect on pupil achievement. The IV regression indicates that NOK 10,000 (US$1,175) higher expenditures per pupil are estimated to raise the exam mark by 0.181. Thus, every sixth pupil will have his/her exam mark raised by one level if the municipality spends NOK 10,000 more on each of them in school. An extra 10% in teacher hours per pupil is estimated to raise the average mark with about 0.251, e.g., one level exam mark rise for one in every four pupils. As for most causal effects identified by "natural experiments", the precision of these estimates is not impressive. Standard errors are from one-third to one-half of the estimated coefficients, implying that the lower bounds of the confidence intervals are close to zero.

With respect to the magnitude of the estimated effects, it is illustrative to relate them to the grade point average (of 11 subjects) for pupils from lower secondary school. The national mean is 3.9 with a standard deviation of 0.8. Assuming that the resource effect is constant across subjects, our estimated expenditure effect amounts to 0.2 standard deviations, and the effect of teacher hours amounts to 0.3 standard deviations.

The IV estimates contrast with the standard cross-sectional estimates that indicate zero, or even negative, effects of school resources. This pattern is consistent with endogenous resource allocation where extra inputs are provided to children with specific needs.

Because families move and cross municipality borders, one might worry that endogenous location (Tiebout sorting) drives our estimates. Our results may also be biased if pupils in hydro power municipalities are inherently different in terms of initial endowments, and if other amenities in hydro power municipalities contribute to their superior school performance. To wrap up all the robustness checks, we find no indication of superior initial endowments among kids born in HPTR, and it seems implausible that sorting through mobility on unobserved ability is driving our estimates. The strongest evidence is given by the estimates for pupils born in the municipality of graduation as well as using municipality of birth as the principle of linking performance and resources, which in both cases are almost identical to what we find in our main analysis. Finally, day care services as an example of correlated amenities are unlikely to explain performance differentials more than ten years later.

While the average achievement of Norwegian students is close to the mean in international studies such as the PISA, a decomposition of the 2003 mathematics-performance examination shows that between-school variation is low in Norway compared with what is found in other countries (see Kjærnsli *et al*., 2004). Tiny performance differentials across schools suggest that the variation in school-specific factors is unimportant. However, it may also reflect the fact that resources do matter *and* that they are distributed across schools partly to level out performance differentials arising from other sources such as pupil composition. The findings in this paper support that the allocation of resources contributes to low performance differentials between schools. Finally, our estimates are likely to represent lower bounds of the effect of school resources. Norway is among the top countries in terms of school expenditures per pupil and our estimates are even identified by the high spending municipality. If there is decreasing returns to school resources, we would expect the effect of school resources to be at the low end in Norway when comparing across countries.

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Figure 1: Distribution of Predicted Expenditures by HPTR

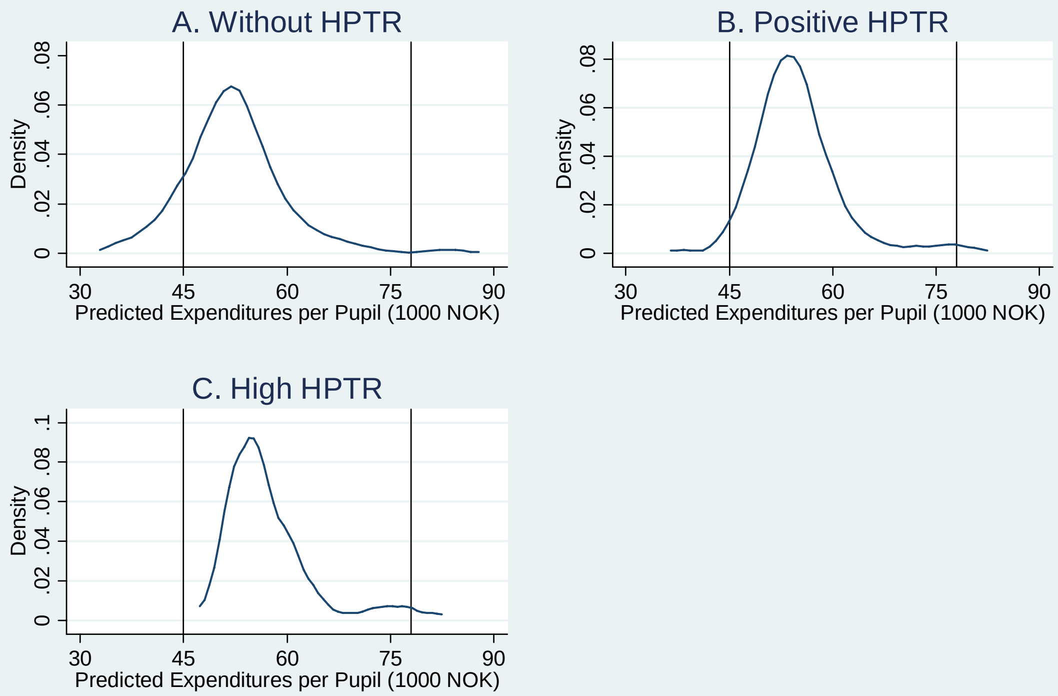

Figure 2: Distribution of Predicted Log Teacher Hours by HPTR

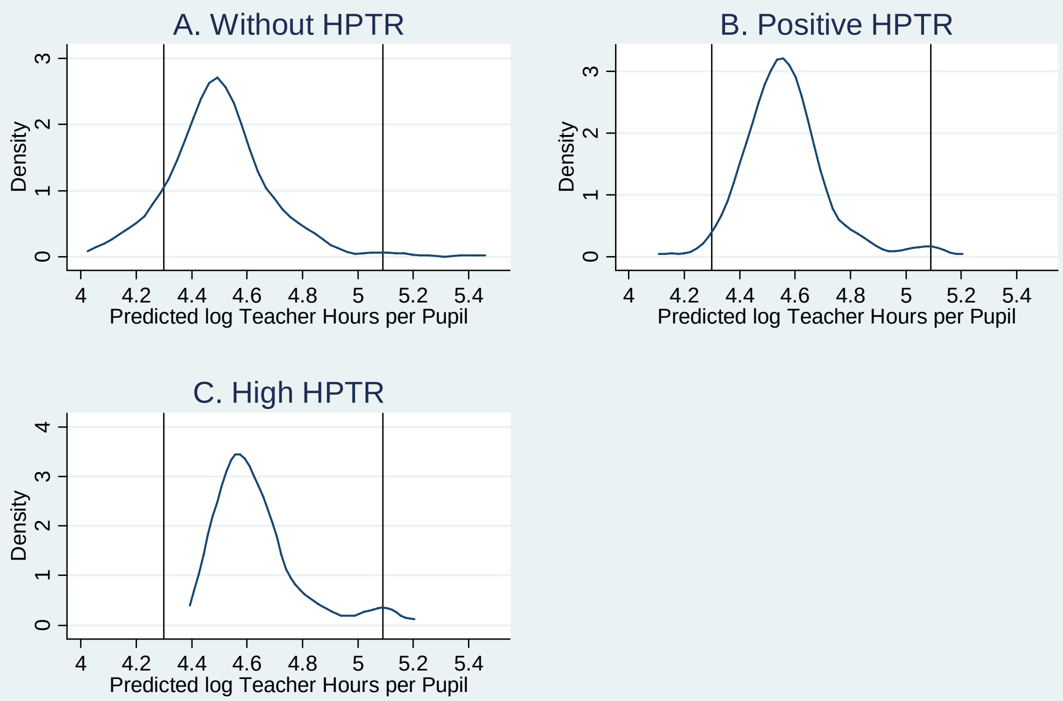

Figure 3: Geographical location of municipalities, by hydropower property tax revenue

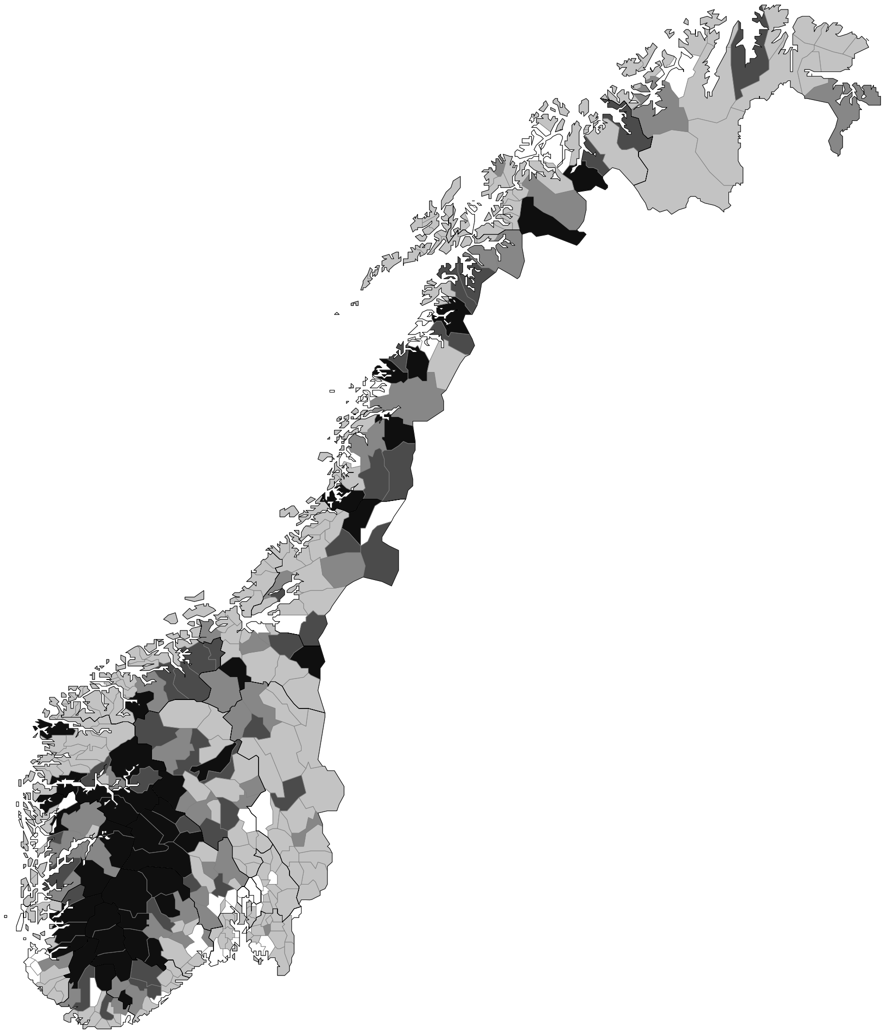

Figure 4: School Resources and Hydro Power Tax Revenues

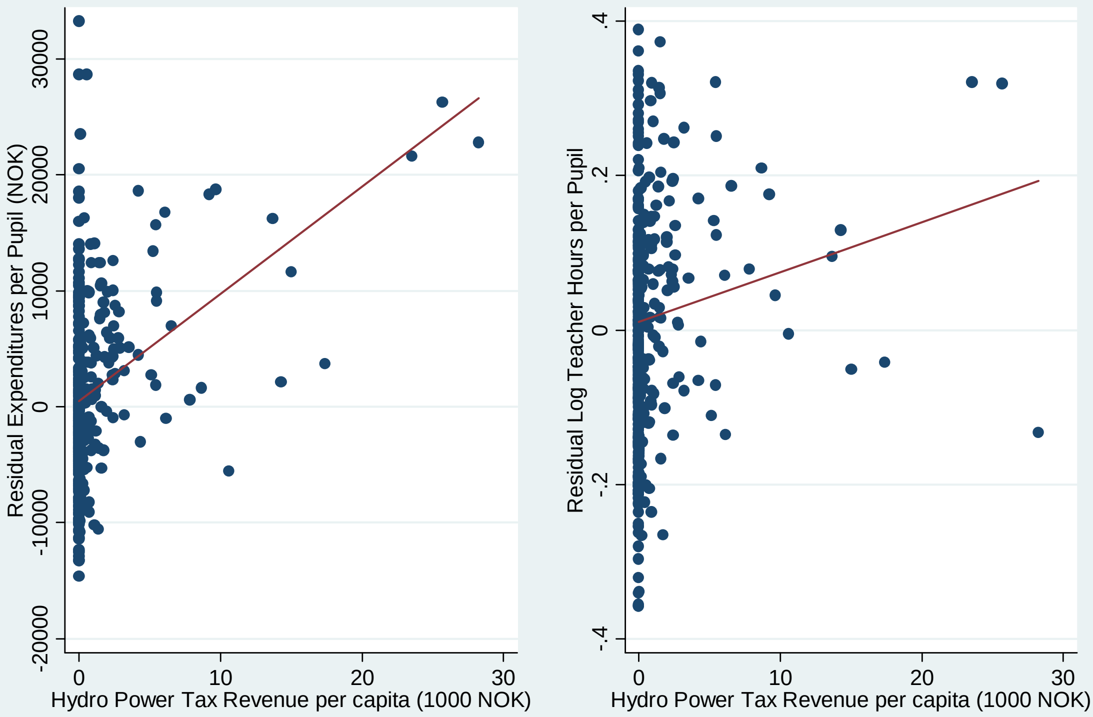

Table 1: School resources, HPTR and municipality characteristics

	(1) All municipalities		(2) Municipalities without *HPTR*		(3) Comparable municipalities	
	Expenditures (NOK 10,000)	Ln Teaching hours	Expenditures	Ln Teaching hours	Expenditures	Ln Teaching hours
Panel A. Descriptive statistics						
Average	5.43	4.54	5.21	4.50	5.44	4.52
Standard dev	1.11	.25	1.03	.25	.97	.20
10^{th} percentile	4.39	4.26	4.28	4.25	4.44	4.28
90^{th} percentile	6.86	4.89	6.60	4.89	6.69	4.82
Panel B. OLS						
Pupils/10000	–3.27 (.054)	–8.37 (1.21)	–3.17 (.616)	–0.834 (.014)	–29.0(3.48)	–6.41(.764)
$Pupils^2/10^7$	1.86 (.037)	.047 (.0083)	1.76(.414)	.461 (.095)	14.9(25.9)	3.16(.559)
$Pupils^3/10^{12}$	–2.47 (.058)	–.061 (.013)	–2.32 (0.65)	–.612(.149)	–2.41 (0.54)	–50.0 (11.4)
Travelling distance (neighbour)	.176 (.021)	.040 (.005)	.163 (.028)	.044 (.0066)	.083 (.025)	.018 (.005)
Travelling distance (zone)	.020 (.007)	.002 (.0016)	.0152 (.011)	.001 (.002)	.041 (.007)	.008 (.002)
Fraction mentally retarded	87 (62)	1.07 (14)	138 (80)	22 (18)	130 (52)	14 (11)
Political left majority	.171 (.084)	.031 (.019)	.263 (.116)	.047 (.027)	.072 (.073)	.020 (.158)
Fraction tertiary education	3.54 (1.54)	.554 (.347)	5.66 (1.90)	.919 (.451)	–.150 (1.43)	.070 (.312)
Pupil composition, parental characteristics						
Fraction tertiary ed.	–1.050(.150)	–.854 (.347)	–1.63 (1.87)	–.982 (.431)	–.067 (1.33)	–.144 (.290)
Fraction upper secondary ed.	–.686 (.138)	–.900 (.311)	–.445 (1.75)	–873 (.404)	–1.28 (1.24)	–.400 (.267)
Family earnings						
Fraction in quintile 1	–1.59 (.860)	–.317(.194)	–2.01 (1.24)	–.406 (.285)	–.468 (.725)	–.326 (.156)
Fraction in quintile 2	–2.06 (.942)	–.368 (.212)	–.872 (1.34)	–.304 (.308)	–.598 (.780)	–.273 (.173)
Fraction in quintile 4	–.06 (1.07)	–.442 (.242)	.361 (1.44)	–.286 (.331)	1.61 (.986)	–.528 (.213)
Fraction in quintile 5	–2.31 (.922)	–.368 (.209)	–2.56 (1.17)	–.501 (.68)	–.219 (.860)	.190 (.185)
Fraction unemployed	2.98 (1.18)	.913 (.265)	5.11 (1.46)	1.15 (.337)	1.79 (1.01)	.675 (.219)
Fraction with disability pension	. 156(.982)	–.036 (.225)	–.605 (1.33)	–.013 (.307)	.984 (.851)	.051 (.185)
Fraction on welfare benefits	.94 (1.85)	.201 (.417)	1.70 (2.46)	–.090 (.565)	2.13 (1.52)	.425 (.330)
Fraction non-Western immigrants	–.66 (2.05)	–.282 (.462)	–.701 (2.48)	–.149 (.572)	–.081 (1.85)	–.011 (.395)
HPTR per capita (NOK 10,000)	.89 (.13)	.065 (.030)			.77 (.011)	.055 (.023)
# Municipalities	429	429	299	299	373	376
# Pupils	51483	51483	43377	43377	26428	27485
Adj R^2	.556	.541	.451	.495	.648	.664
Marg. Adj R^2	.053	.0047	Na	Na	.050	.004

Note: # of pupils (as a municipality characteristic) refers to 1^{st}–10^{th} grades for expenditures and 8^{th}–10^{th} grades for teacher hours.

Table 2: School resources per pupil and municipality characteristics, by hydropower tax revenue among comparable municipalities (mean values)

	Comparable municipalities			
	No *HPTR*	Low *HPTR*	Medium *HPTR*	High *HPTR*
Municipality level				
Expenditures per pupil (NOK)	52,598	52,578	58,016	64,497
Teaching hours per pupil	93.8	89.5	106.6	111.4
HPTR per capita (NOK)	0	402	1,270	6,797
Pupils in 1^{st}–10^{th} grades	872	1,095	502	376
Travelling distance (neighbour)	3.51	3.10	4.03	5.08
Travelling distance (zone)	7.93	8.01	9.52	11.28
Left majority	.236	.364	.342	.250
Fraction tertiary education	.164	.171	.146	.157
Fraction mentally retarded, 6–15	.073	.057	.064	.063
Pupil composition, parental characteristics				
Fraction with tertiary education	.317	.332	.290	.306
Fraction with secondary education	.632	.627	.662	.645
Family earnings				
Fraction in quintile 1	.207	.205	.250	.242
Fraction in quintile 2	.251	.252	.268	.260
Fraction in quintile 4	.184	.186	.157	.159
Fraction in quintile 5	.108	.100	.071	.078
Fraction unemployed	.061	.052	.057	.051
Fraction with disability pension	.104	.109	.111	.100
Fraction on welfare benefits	.035	.034	.039	.032
Fraction non-Western immigrants	.022	.021	.021	.015
# Municipalities	250	44	38	44

Note: Sample of municipalities with comparable (predicted) expenditures per pupil. Sample characteristics are very similar for municipalities with comparable levels of teacher hours per pupil. Expenditure per pupil refers to 1^{st}–10^{th} grades, while teacher hours per pupil covers 8^{th}–10^{th} grades.

Table 3A: Municipality characteristics, by level of HPTR and their five nearest (matched) neighbours: Expenditure sample (mean values)

	Low *HPTR*		Medium *HPTR*		High *HPTR*	
	Low	Matched (with *HPTR* = 0)	Medium	Matched (with *HPTR* = 0)	High	Matched (with *HPTR* = 0)
A. Expenditure per pupil						
	52,578	50,793	58,016	53,333	64,497	55,832
B. Municipality characteristics						
HPTR per capita	.402	0	1,270	0	6,797	.0
# pupils	1095	986	502	668	376	514
Travelling distance (neighbour)	3.10	3.22	4.03	3.98	5.08	4.40
Travelling distance (zone)	8.01	7.05	9.53	8.81	11.28	9.53
Political left majority	.364	.227	.342	.242	.250	.259
Fraction tertiary education	.171	.167	.146	.154	.157	.156
Fraction mentally retarded	.0006	.0007	.0006	.0007	.0006	.0007
Pupil composition, parental characteristics						
Fraction with tertiary education	.332	.322	.299	.302	.306	.302
Fraction with sec. education	.627	.631	.662	.647	.645	.642
Family earnings						
Fraction in quintile 1	.205	.195	.250	.208	.242	.214
Fraction in quintile 2	.252	.248	.268	.265	.260	.270
Fraction in quintile 4	.186	.188	.157	.178	.159	.180
Fraction in quintile 5	.100	.120	.071	.094	.078	.082
Fraction unemployed	.052	.056	.057	.059	.051	.069
Fraction with disability pension	.109	.105	.111	.102	.100	.106
Fraction on welfare benefits	.034	.032	.039	.033	.032	.034
Fraction non-Western immigrant	.021	.023	.021	.018	.015	.017
# Municipalities	44	44·5	38	38·5	44	44·5

Table 3B: Municipality characteristics, by level of HPTR and their five nearest (matched) neighbours: Teacher hours sample (mean values)

	Low *HPTR*		Medium *HPTR*		High *HPTR*	
	Low	Matched (with *HPTR* = 0)	Medium	Matched (with *HPTR* = 0)	High	Matched (with *HPTR* = 0)
A. Teacher hours per pupils						
	89.49	87.02	107.00	97.51	111.38	101.0
B. Municipality characteristics						
HPTR per capita	402	.0	1,270	.0	6,797	.0
# pupils	1095	1050	504	649	376	535
Travelling distance (neighbour)	3.10	3.11	4.25	4.05	5.08	4.52
Travelling distance (zone)	8.01	7.37	10.06	9.02	11.28	9.90
Political left majority	.364	.200	.316	.237	.250	.305
Fraction tertiary education	.171	.171	.146	.152	.157	.152
Fraction mentally retarded	.0006	.0007	.0007	.0007	.0006	.0007
Pupil composition, parental characteristics						
Fraction with tertiary education	.332	.328	.287	.305	.306	.302
Fraction with sec. education	.627	.628	.665	.642	.645	.642
Family earnings						
Fraction in quintile 1	.205	.200	.254	.217	.242	.229
Fraction in quintile 2	.251	.247	.268	.269	.260	.266
Fraction in quintile 4	.186	.186	.156	.172	.159	.168
Fraction in quintile 5	.100	.118	.071	.088	.078	.080
Fraction unemployed	.052	.056	.058	.065	.051	.072
Fraction with disability pension	.109	.103	.115	.107	.100	.107
Fraction on welfare benefits	.034	.032	.039	.033	.032	.035
Fraction non-Western immigrant	.021	.024	.021	.018	.015	0.19
# Municipalities	44	44*5	38	38*5	44	44*5

Table 4: School resources and pupil performance: Wald estimates based on neighbouring municipalities

	(1) Marks Differential	(2) Wald Expenditures (NOK 10,000)	(3) Wald Ln (Teacher hours)/10
I. Mean (on scale 1 to 6)			
HPTR > 0 vs no	.032 (.020)	.070 (.046)	.044 (.024)*
Low *HPTR* vs no	.021 (.029)	.106 (.165)	.008 (.043)
Med *HPTR* vs no	–.019 (.030)	–.039 (.065)	–.012 (.029)
High *HPTR* vs no	.111 (.048)**	.113 (.050)**	.117 (.041)***
II. Basic skills (proportion with mark > 2)			
HPTR > 0 vs no	.007 (.009)	.015 (.020)	.019 (.011)*
Low *HPTR* vs no	.002 (.016)	.010 (.086)	.009 (.020)
Med *HPTR* vs no	–.001 (.017)	–.002 (.034)	.007 (.014)
High *HPTR* vs no	.023 (.014)	.025 (.016)	.036 (.021)*
III. High skills (proportion with mark 5 or 6)			
HPTR > 0 vs no	.019 (.007)	.041 (.017)**	.018 (.008)**
Low *HPTR* vs no	.006 (.011)	.027 (.047)	.001 (.014)
Med *HPTR* vs no	.017 (.010)	.032 (.022)	.009 (.010)
High *HPTR* vs no	.052 (.017)***	.056 (.018)***	.041 (.012)***

Note: Wald estimates based on (Mean Differential Performance/Mean Differential Resources). Resource differentials are displayed in Table 3. The reported performance differentials in column (1) are for the expenditure-matched sample, but the differentials for the teacher hours-matched samples are very similar. The log (teacher hours per pupil) estimate is divided by 10 to have an interpretation of (approximately) a 10% increase in teacher hours per pupil. Standard errors are in parentheses. */**/*** indicate statistical significance at the 10%/5%/1% level respectively. Observations (matched pairs) are weighted with the inverse of the sum standard errors of the estimated municipality performance effects.

Table 5: School resources and pupil performance; Comparable municipalities: OLS and IV estimates

	(1) OLS No controls	(2) Family background adjusted OLS	(3) Family background adjusted + municipality characteristics. OLS	(4) IV
Panel A. Effect of increased expenditures (NOK 10,000) per pupil on				
I. Mean	.005 (.015)	.029 (.013)**	–.014 (.021)	.181 (.063)***
II. Basic skills	–.002 (.005)	.006 (.004)	–.012 (.007)	.040 (.019)**
III. High skills	.000 (.004)	.007 (.004)	–.004 (.007)	.048 (.021)**
Panel B. Effect of more teacher hours (ln(hours per pupil)/10) on				
I. Mean	.004 (.006)	.018 (.006)***	.001 (.010)	.252 (.124)**
II. Basic skills	.001 (.002)	.005 (.002)***	–.001 (.003)	.048 (.026)*
III. High skills	.001 (.002)	0.004 (0.002)**	.001 (.003)	.068 (.037)*
Family characteristics	No	Yes	Yes	Yes
Municipality controls	No	No	Yes	Yes
# Municipalities	373/376	373/376	373/376	373/376

Note: Dependent variables are average marks (row I), fraction with basic skills (row II) and highly skilled (row III) at the municipality level. Standard errors are in parentheses. */**/*** indicate statistical significance at the 10%/5%/1% level respectively. Observations are weighted as described in section 2.

Table 6: School resources and pupil performance; All municipalities: OLS and IV estimates

	(1) OLS No controls	(2) Family background adjusted OLS	(3) Family background adjusted + municipality characteristics. OLS	(4) IV
Panel A. Effect of increased expenditures (NOK 10,000) per pupil on				
I. Mean	.003 (.013)	.033 (.011)***	.004 (.016)	.149 (.047)***
II. Basic skills	.003 (.004)	.010 (.004)**	–.002 (.005)	.032 (.014)**
III. High skills	.004 (.004)	.008 (.004)**	.000 (.005)	.036 (.015)**
Panel B. Effect of more teacher hours (ln(hours per pupils)/10) on				
I. Mean	–.001 (.005)	.016 (.005)***	.005 (.007)	.170 (.077)**
II. Basic skills	.003 (.002)	.006 (.001)***	.002 (.002)	.033 (.017)*
III. High skills	.000 (.002)	.004 (.002)**	.001 (.002)	.063 (.035)*
Family characteristics	No	Yes	Yes	Yes
Municipality controls	No	No	Yes	Yes
# Municipalities	429	429	429	429

Note: Dependent variables are average marks (row I), fraction with basic skills (row II) and highly skilled (row III) at the municipality level. Standard errors are in parentheses. */**/*** indicate statistical significance at the 10%/5%/1% level respectively. Observations are weighted as described in section 2.

Table 7: Associations between HPTR (10 000 NOK) and pupil (municipality fixed) endowments in terms of Birth weight, Head size and Apgar score

	All municipalities	Expenditure sample	Teacher hours sample
Birth weight (ln kg)	-.0007	-.0012	-.0008
	(.0008)	(.0011)	(.0008)
Head size (cm)	-.0002	.0083	.0021
	(.0096)	(.0118)	(.0090)
Apgar 5 score	-.0114	-.0246	-.0170
	(.0106)	(.0105)	(.0085)
Controls individual regression to estimate municipality fixed effects: Gender, age of mother, mother's years of schooling, father's years of schooling, family earnings, parents' marital status number of siblings, number in the birth order,			
# Individual pupils	41961	20305	21078
Municipality level controls: All variables included in the IV estimates, see Table 3A-B.			
# Municipalities	429	373	376

Note: Apgar score is from the general test of a child health on a scale from 1-9 here measured 5 minutes after birth.

Table 8: Graduation municipality seniority by HPTR percent

	All municipalities	Comparable municipalities		Municipalities with *HPTR* > 0
		Expenditures	Teacher hours	
Panel A. Pupil seniority in graduation municipality				
Less than 3 years	4.9	5.3	5.4	4.1
4–6 years	4.7	5.0	5.0	3.9
7–10 years	7.6	7.6	7.7	6.0
11–15 years	17.2	16.7	16.8	15.6
16 years (Born in municipality)	65.6	65.4	65.1	70.4
B. Mother's mobility				
Mother in graduation municipality in 1980	35.0	32.8	32.7	38.8

Table 9: Mobility and observed family background; Effects on the probabilities of graduation in high and medium level HPTR municipalities: PROBIT estimates

	Probability of graduation in municipality with			
	High *HPTR* born in a municipality with		Medium *HPTR* born in a municipality with	
	HPTR = 0	*HPTR* > 0	*HPTR* = 0	*HPTR* > 0
Panel A. All pupils				
Predicted mark	–0.2247 (0.0590)***	0.1092 (0.0480)**	–.1435 (.0308)***	.0423 (.0481)
Constant	–1.9779 (0.1984)***	–1.2851 (0.1647)***	–1.6594 (.1057)***	.8812 (.1640)***
Pseudo R^2	0.008	0.001	.0031	.0002
# pupils	43,092	4,613	43,092	4,613
Panel B. Pupils who moved during 1989–2002				
Predicted mark	–0.1701 (0.0636)***	–0.2041 (0.1370)	–.0882 (.0360)**	–.1187 (.0899)
Constant	–1.6135 (0.2141)***	–0.9530 (0.4553)**	–1.1495 (.1236)***	–.4134 (.3039)
Pseudo R^2	0.005	0.006	.0012	.0019
# pupils	9226	891	9226	891

Note: Standard errors are in parentheses. */**/*** indicate statistical significance at the 10%/5%/1% level respectively.

Table 10A: Expenditures; Alternative sample definitions: Comparable municipalities

	Pupils born in Norway by Norwegian parents	Pupils born in graduation municipality	Pupils born in graduation municipality, and mother lived in municipality since 1980	Municipality of graduation replaced by municipality of birth
	(1)	(2)	(3)	(4)
I. Mean				
Wald	.074	.098	.084	.099
	(.047)	(.052)*	(.064)	(.067)
OLS	–.013	.004	.000	-.000
	(.021)	(.038)	(.030)	(.014)
IV	.184	.206	.149	.156
	(.063)***	(.101)**	(.081)*	(.059)**
II. Basic skills				
Wald	.006	–.011	.045	.036
	(.021)	(.029)	(.027)	(.029)
OLS	–.011	–.010	–.012	-.008
	(.006)	(.007)	(.009)	(.005)*
IV	.040	.045	.044	.037
	(.019)**	(.021)**	(.025)*	(.017)**
III. High skills				
Wald	.043	.040	.037	.011
	(.017)**	(.020)**	(.021)*	(.024)
OLS	–.004	.000	.004	-.001
	(.007)	(.008)	(.009)	(.004)
IV	.057	.055	.040	.047
	(.021)***	(.023)**	(.025)	(.020)**
# pupils	25486	17444	8450	25542

Note: Dependent variables are average marks (Panel A, I), Fraction with basic skills (Panel A, II) and high skills (Panel A, III) at the municipality level. Standard errors are in parentheses. */**/*** indicate statistical significance at the 10%/5%/1% level respectively. Observations are weighted as described in section 2.

Table 10B: Teacher hours; Alternative sample definitions: Comparable municipalities

	Pupils born in Norway of Norwegian parents	Pupils born in graduation municipality	Pupils born in graduation municipality, and mother lived in municipality since 1980	Municipality of graduation replaced by municipality of birth
	(1)	(2)	(3)	(4)
I. Mean				
Wald	.045	.055	.035	.071
	(.024)*	(.027)**	(.032)	(.027)**
OLS	.001	.007	.011	.003
	(.009)	(.018)	(.014)	(.006)
IV	.250	.285	.166	.206
	(.122)**	(.165)*	(.105)	(.110)*
II. Basic skills				
Wald	.014	.016	.018	.022
	(.009)	(.012)	(.013)	(.018)
OLS	–.001	–.001	–.000	-.003
	(.003)	(.003)	(.004)	(.002)
IV	.050	.057	.040	.048
	(.028)*	(.033)*	(.027)	(.027)*
III. High skills				
Wald	.021	.014	.007	.013
	(.009)**	(.010)	(.008)	(.011)
OLS	.001	.003	.005	.001
	(.003)	(.004)	(.004)	(.002)
IV	.080	.069	.040	.059
	(.039)**	(.037)*	(.028)	(.034)*
# pupils	26442	18048	8736	25214

Note: Dependent variables are average marks (Panel A, I), Fraction with basic skills (Panel A, II) and high skills (Panel A, III) at the municipality level. Standard errors are in parentheses. */**/*** indicate statistical significance at the 10%/5%/1% level respectively. Observations are weighted as described in section 2.