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ABSTRACT

Pennies from Heaven? Using Exogenous Tax Variation to Identify Effects of School Resources on Pupil Achievements*

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 positive IV estimates contrast with the standard cross-sectional estimates that reveal no effects of extra resources.

JEL Classification: I21, I28, J00

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1. Introduction

While knowledge of how school resources affect student achievement is crucial for policy design, the research literature remains inconclusive.[1] In part, this reflects the challenges of empirical identification when school authorities, teachers and parents all make choices that influence associations between pupil ability and school resources. First, school inputs 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. If school districts allocate money in order to compensate (or reinforce) differences in child abilities, the simple least squares estimator of the causal relationship between expenditure and performance will be biased.[2] Second, Tiebout sorting of families across schools districts based on taste for education quality may provide the more able pupils with the highest level of school resources. Finally, as school resources are multidimensional, causal effects of a single input can be hard to identify. For example, the flip side of an exogenous variation in class size (Angrist and Lavy, 1999) is likely to be compensating variation in other inputs like e.g. teacher hours or quality.

This study aims to identify the effects of per pupil school expenditures on final exam achievement at age 16 by the end of lower secondary school. Our approach exploits the location of an immobile natural resource – waterfalls – and a set of institutional features for taxing this resource that generate *exogenous expenditure variation* across school districts. Natural resources often generate economic rents 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) provide access to an immobile tax source. Nature determined the direction of the waterfalls, 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

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[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.

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.

This 'exogenous' expenditure variation across municipalities are used in two ways. The main approach is a two stage least squares model where school resources are instrumented by the hydro power tax revenue (HPTR). Supplementary evidence is provided by a nearest-neighbour matching estimator where we compare with municipalities receiving zero HPTR on the basis of fitted values from a regression of school resources on a rich set of municipality characteristics. Being aware of the fact that standard Tiebout sorting based on taste for investments in children could partially explain a positive correlation between pupil performance and high hydro power tax revenues, we combine the above approaches with a set of robustness checks. The influence from Tiebout sorting on the estimates is after all an empirical question.[3] For a start we have access to an unusual rich set of controls for observable differences across families that influence demand for spending on schooling, and a rich set of observable differences across HPTR and non-HPTR municipalities. In addition, it is reasonable to believe that parents who desire high education spending also invest more heavily in their children's achievements in other ways such as for instance prenatal care. Since the health of a newborn child is likely to reflect unobserved parental investment before birth, and also positively correlated with parents' unobserved post-birth investment in children, we check for health status of newborn children across municipalities. Furthermore, rich municipalites may invest more in other amenities for children such as high quality day care centres, which may contribute to explaining achievement differentials at age 16. We test for differences in day care coverage and for quality heterogeneity in day cares across municipalities. In order to eliminate a spurious correlation between HPTR and pupil achievement attributable to Tiebout sorting after the pupils' birth, we restrict the analyses to the sample of pupils born in the graduation municipality. Finally, we replace municipality of graduation with municipality of birth as an alternative approach to adjust for post-birth location on the basis of school resources. All these checks strongly support the assumption that parental location tastes for education are orthogonal to other unobserved determinants of pupil achievement.[4]

Our main findings are as follows. Standard least squares estimates indicate that money to schools does not matter. However, when using hydropower tax revenues as an instrumental variable, school resources are found to have a significantly positive impact on pupil exam scores. The IV results indicate that NOK 10,000 (US$ 2,000) higher annual expenditures per pupil are estimated to raise the exam mark by about 0.2. Thus, every fifth pupil will have his/her exam mark raised by one level on a a scale from one to six, if the municipality spends NOK 10,000 more per year 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. Higher expenditures are partly used to increase teacher input, and our evidence shows that a positive impact of a more teacher hours per pupil is part of the reason why money matters. None of the robustness checks suggest that our estimates are driven by unobserved pupil heterogeneity, due to e.g. Tiebout sorting, which would violate our exclusion restriction that HPTR only affects achievement via the level of school resources.

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 ndecide 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

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[3] Recent empirical work testing sorting across communities according to public good expenditures does not seem to support Tiebout mechanisms as a first order motive for residential choice across states or municipalities (Rhode and Strump, 2003). Other factors such as such as employment and closeness to families and friends appear to be the most important. This interpretation is supported by evidence in Rothstein (2005).

[4] 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.

more teacher hours, or extra resources of another kind. Even parents may compensate also for class size changes by exercising more effort guiding children put in larger classes (Bonesrønning, 2003). 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. Apparently, the conclusion on whether resources matter (at the margin) seems to vary systematically with how the effects are identified. The value added approach estimates school production functions by means of longitudinal data on pupil outcomes and typically finds no impact of school resources on student performance (see overviews in Hanushek (1996, 2007).[5] More recent studies address more directly the endogeneity issues outlined above using different types of exogenous variation in resources. Often, these studies report positive effects of school resources. Two approaches are used. 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

[5] See for example Lindahl (2005), Bonesrønning (1996) for Nordic studies in this tradition. Rothstein (2007) gives a critical discussion of the the value added approach.

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, focusing on institutional features that provide exogenous assignment of different school environments to pupils. Our literature review will focus on this approach since it is most relevant for our study.

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). Among Nordic studies, Browning and Heinesen (2007) 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 (2005), 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.[6] Consequently, teacher-pupil ratios defined at the grade level represents a more relevant input measure, for methodological reasons as well as in terms of 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. 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 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

[6] 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.

provided at the municipality level.[7] 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 total school expenditures. 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.

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

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

In the resources equation (1), we use total expenditures per pupil to measures of SR_m, where m indicates that all variables are at the municipality level.[8] 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 and the need for an instrument arises from the potential interdependence between u_m and v_m. Sorting on unobserved pupil ability as well as compensating resource allocation will generally create a correlation between these two

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

[8] In section 7, we also report the effects of teacher hours per pupil.

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:

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

where i denotes the individual, and $M_{im} = 1$ if pupil i graduated in municipality m, zero otherwise. Thus, $A_m = \widehat{\alpha}_m$. 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).[9]

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

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[9] 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).

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. 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 relevance of bias from Tiebout sorting is an empirical question, related to how location decisions are made. Consider a sequence where the decision about work is made first, influenced by the arrival of job offers. Work then determines the labour market area or metropolition area, and given this location, decision of where to exactly locate within a travel to work area is taken. In the second choice the quality of the school plays a role. Related to the first type of location decision, recent research attempting to test the importance of Tiebout sorting across municipalities and counties using ca 150 years of data, do not find strong support for Tiebout sorting (Rhode and Strump, 2003). Their findings do not support Tiebout sorting as a primary motivation. Research which find that school quality matters for location are typically about decisions where to live *within* a metropolitan area; Black (1999) in Boston, Machin and Redding (2003) in London and for a Norwegian study on Oslo; Machin and Salvanes (2007). Our study, however, is based on school differences across municipalities in Norway, and we would not expect that Tiebout effects should be prominent in the location decision based on the evidence given above.

Our identification strategy does not address the problem of endogenous location explicitly, but we report several tests to check whether sorting on unobserved family factors can explain our results. 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, based on subsample of pupils born in the municipality of graduation. To avoid leaving movers out of the data, we also redo the analyses where we replace municipality of graduation with municipality of birth.

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. Technically, the resource effect we estimate is the impact of a change in the average annual flow of expenditures (or teacher hour input) affecting the pupil throughout their final three years before graduation. But, as resource exposure is highly correlated across grades, the estimated parameter can be interpreted as the effect of a permanent change in school input throughout all years of compulsory schooling.

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 (1st–10th 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.[10] 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.

Expenditures. Municipalities annually report expenditures by sector of activity to Statistics Norway. We use total expenditure on primary and lower secondary schools (1st–10th 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 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).

Teacher hours. Every school provides annual information on (i) the number of pupils by grade and (ii) the total hours of instruction for 8th–10th 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.

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.

[10] 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.)

Pupil characteristics and their family background

To measure Ci and Fi 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.

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.[11] 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

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

could exist if entrepreneurial people, with clever children, clustered in areas with power plant investments.[12]

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, including taxes from residential houses, 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)[13], 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 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*.[14]

[12] 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.

[13] 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.

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

Determination of school resources

To provide information about the scaling of school spending, Panel I Table 2 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 10^{th} percentile spends NOK 43,900 (US\$6,300) and the 90^{th} 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 2, Panel B. Our focus is on the *HPTR* parameter, estimated conditional on other municipality characteristics. The effect of hydropower tax revenues on expenditures is significantly positive, with a t-value of about seven. Based on all municipalities, the point estimate is close to unity: If hydropower tax revenues *per capita* increase by one NOK, expenditures *per pupil* increase by NOK 0.92. If the ten cohorts of pupils count for 15 per cent of the population, an extra NOK collected in annual hydropower tax revenues will give an increase in school spending of 0.14 NOK. Thus, the marginal spending propensity is lower than the average school expenditure share of total municipality spending (about 0.3).

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 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.[15]

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. The results for family earnings, i.e., the fractions in the lower and upper quintiles, are mixed. The high correlation between family characteristics, within counties, makes it hard to get precise estimates of each of them.[16] It is hard to see a clear pattern of local priorities, which partly reflects the limited variation when county fixed effects are included.

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

[15] 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.

[16] 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.

expenditures (teacher hours) within the range 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 2).

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

Considering the set of comparable municipalities, Table 3 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 both resources and (unobserved) pupil ability. Figure 2 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 margial effect of *HPTR* on drops from 0.92 to 0.81 when we restrict the analysis to municipalities with a comparable expenditure structure (see column (3) (*comparable municipalities*) in Table 2, which corresponds to the first-stage regressions in our IV analysis). However, even across comparable municipalities, *HPTR* is a powerful instrument for school spending. Figure 3 displays the relationship between *HPTR* and residual expenditures (left). For illustration we also report for teacher hours residual (right). Residual expenditures are defined as the difference between observed and predicted expenditures based on parameters in column (3) of Table 1. A similar resource equation is estimated for teacher hours, Table A1 in appendix. In other words, the two panels of Figure 3 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 expenditure.

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 2, 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 Table 4, we report the level of school resources in the municipalities with *HPTR* and their neighbours. Municipalities with low *HPTR* have slightly higher school expenditures than their neighbours. When *HPTR* is substantial, municipalities also spend significantly more on schools than their neighbours. Panel B displays 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 due to different, and presumably superior, performance among students in *HPTR* municipalities. Since the performance scale (1 to 6) is not purely cardinal, the average mark may be misleading as an aggregated outcome measure. Partly for this reason, we also look at the impact on the proportion with "basic skills" (mark above 2) and the proportion with high skills (mark 5 or 6). In practice, however, the marks are used cardinally as they are added across subjects to get an overall score. This score serves as the main admission criterion which determines the pupils' set of alternative high schools when leaving compulsory schooling at age 16.

Column (1) in Table 5 displays the performance differentials, measured by average exam marks and skill group distributions. These differentials are adjusted for family background characteristics as discussed in section 2, i.e., $A_m = \widehat{\alpha}_m$ from estimation of (3). When we compare all *HPTR* municipalities with their matched neighbours, the differential in average marks is .051, and a slighty higher fraction obtains basic skills (.014 differential in Panel II), while significantly more pupils get the highest scores (.022 differential in Panel III) in *HPTR* municipalities. 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.

Column (2) in Table 5 provides the Wald estimates, which relate the average outcome differentials in column (1) to the expenditures 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, but only significant at the 10%-level. At the lower end of the achievement distribution, the Wald estimator suggests a small and positive effect on basic skills (Panel II) from, but it is not significant. The impact on the proportion with high skills is larger and significant (Panel III), with an estimate of 0.045. If expenditures are raised by NOK 10,000, the fraction of pupils with the two marks increases with 4.5 percentage points.

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, although only at the 10%-level for basic skills. The effect of increased expenditures in the order of NOK 10,000 on the mean is 0.185, suggesting that close to one in five pupils would have their exam mark raised by one level. All in all, the Wald estimates of Table 5 clearly suggest that (large) differences in school resources do matter.

Turning now to our preferred IV approach, the main results are given in Table 6. Column (1) reports the bivariate least squares regression coefficients and reveals that school expenditures are basically uncorrelated with measures of pupil performance. 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 on individual family background, we do find significantly positive effects of expenditures, column (2) in Table 6. 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 .219. Thus, every fifth 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. Compared to the Wald estimate based on the municipalities with high HPTR in Table 5, our IV estimate is very similar (mean effects are .184 and .219, respectively).

When we look at the resource effects across the achievement distribution our estimates suggest that the effects are significant for the least as well as the most able pupils (see rows II and III column (4), Table 6). IV estimates are significant for both basic skills and high skills. The point estimates are similar and implies that the share *without* basic skills is reduced substantially with about 5.5 percentage points, which is a fairly large effect as 21.2 percent of the pupils did not possess basic skills. High performing students also benefit as the estimate suggests that the fraction with top marks is raised by 4.8 percentage points, compared to an average of 17.8 percent. Thus, school expenditure seems to affect achievement throughout the ability distribution.

Compared with all OLS estimates with municipality controls in Table 6, all 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.

There is no obvious standard which can be used to get a sense of whether our effects are large or small. Most studies using IV-techniques or actual experiments focus on a specific cost component such as class size, and not an overall cost measure. In the STAR project as reported in Krueger (1999), the experiment reduced class size by a third (by 7-8 pupils). This reduction gave an increase in performance of 0.22 standard deviations. Assuming (as Krueger does) that this increases costs proportionally, we can calculate the effect of an increase of NOK 17,919 from the mean of NOK 54,300. Again using the results for the IV-estimation from Table 6 where the mean effect is 0.219 (for a NOK 10,000 increase), an increase of NOK 17,919 would thus provide an increase in performance of 0.28 standard deviations in performance, where one standard deviation in performance is 1.11 as given in Table 1. Thus, our effects are in the same ballpark as those found in the STAR project.

6. Robustness checks

The main results are based on comparable municipalities with a similar set of characteristics. Even if we prefer this restriction, it turns out that it is not crucial for our conclusions. The results based on all municipalities are reported in Table 7, and they are very similar. While point estimates are slightly lower, the effects are of the same order of magnitude, and they remain statistically significant.

The instrument is based on revenues from property taxation of hydropower plants. The *tax rate* is chosen by the municipality, subject to a maximum of .7 percent of the tax base. One might argue that communities with high preference for local goods quality also prefer high property taxes and may attract education-oriented families. However, almost all municipalities with hydro power plants choose to tax at the maximum rate and our estimates are unchanged if we use the tax base as our instrument.[17]

Our identification is based on cross-sectional variation across municipalities and even if we condition on a large number of family characteristics. The following sections address issues of potential concern. First, the pupils in the municipalities with hydro power incomes may be *inherently* different in terms of endowments or family investments, conditional on the rich set of parental characteristics. Second, selective mobility in and out of hydro power municipalities may affect the results. Finally, 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. We look empirically at the implications of these alternative explanations, and conclude that the results are hardly affected in any substantial way.

Are pupil endowments or family investments different in hydro power municipalities?

The first concern is whether pupils are different in hydro and non-hydro municipalities. Our results could be explained by unobserved ability differentials or family investments positively correlated 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, our 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.[18] 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). Presumably, these endowments partly reflect prenatal family investment or behaviour of the mother like e.g. smoking, drinking og drug use.Table 8 displays the least 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 our main (IV) analysis of school resource effects. We find no association whatsoever for birth weight or head size. The negative 'effect' of *HPTR* on the Apgar-5 score suggests a 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 well 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. Pupils who moved during school years experienced resources different from that observed at graduation. Thus, mobility 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. Tiebout sorting models would predict that families with preference for high quality local goods will tend to locate in municipalities with *HPTR* and their children may have characteristics or experience family environments that raise school performance.

[17] Not reported, results available on request.

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

First, we track the residential municipality of pupils until graduation. About 83.5% of the pupils have lived in their graduation municipality throughout all ten years of school (see Table 9). 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 9), but it seems unlikely that a minor difference of this magnitude will have any sizeable impact on our resource effect estimates.

Mobility is examined in Table 10. 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 a concern that our estimates are driven by systematic sorting. The estimates in Table 10 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 or medium *HPTR*. Estimates for all pupils and the subsample of those who actually moved during the years preceding graduation are reported. 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. All in all, the relationships between family characteristics and mobility do not indicate that our resource effect estimates are upward biased.

Our final checks on the impact of mobility are reported in Table 11. First, we estimate the school resource effects, conditional on seniority in the municipality of graduation. Column (1) in Table 11 displays the effects of expenditures, based on Norwegain-born pupils. They turn out to be almost identical to our main results in Tables 5 and 6. When we restrict the analyses to pupils born in their graduation municipality in column (2), the estimates are again very similar. This suggests that the bias from misrepresentation of school resource exposure for movers is negligible. 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 or family investments. In column (3) of Table 11, 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 locations coincide for about two thirds of the sample, as shown in Table 9. We would expect a lower effect of school resources simply because measurement error is introduced for a substantial fraction of the pupils.

To get an estimate on how much of the reduction in the IV-estimate that can be attributed to measurement error when we allocate pupils to school resources in their municipality of birth (under a null hypothesis that our original estimate reflects true resource effects and not selective migration), we performed a simple Monte Carlo simulation: A_m was replaced by a weighted average of the estimated municipality fixed effect from (3) and a random draw from the distribution of estimated municipality fixed effects, with the share of in-born graduates and moved-in graduates in the municipality as weights, respectively. If selective movers really were the main driver of our results, the estimated resource effect based on simulated data should be significantly lower. This is not confirmed. From 10,000 simulations, the average IV-estimate for the effect on the mean is 0.170, with a standard deviation of 0.051. The estimate based on municipality of birth in column (3) is slightly lower than our main estimates and very much in line with we found in our measurement error exercise, and the IV estimates remain statistically significant.

Using municipality of birth eliminates the effect of selective migration taking place after the child's birth. However, the estimates may still be influenced by parents who moved after having their first child, but before the birth of the child in our sample. Restricting the sample to first-born children, our IV-mean estimate in Panel I drops somewhat, but it is still highly positive and significant. When we replace municipality of graduation with municipality of birth for this sample, the IV-estimate of the effect on the mean drops to around 0.12, and is not statistically significant. However, this estimate is again similar to what we get from a measurement error simulation exercise similar to the one described above. Note that the fraction of stayers is smaller in column (5). This is probably because parents in the sample of first-borns are younger than in the full sample, and more mobile. The measurement error effect is thus larger. To conclude, our estimates seem quite robust to the impact of selective migration.

Can other amenities in hydro power municipalities explain achievement differentials?

Municipalities with hydro power plants have wealthy local authorities who provide a wide range of high quality services like libraries, sport fields and public day care centres. One might wonder whether such amenities actually drive the superior exam performance at age 16 among pupils in *HPTR* municipalities. Empirical studies suggest that early education and high quality child care services have favourable long-term effects on development and educational attainment, even if the evidence is mixed and hard to establish due to obvious selection issues (Currie, 2001).[19]

Using additional data of day care centre coverage by municipality, year and children's preschool age, we find that the national coverage of day care for children aged 1-6 was about 50 per cent during relevant years (1988-1993), with a substantially higher coverage in municipalities with *HPTR*.[20] Controlling for municipality characteristics we find that an increase in *HPTR* with 10,000 NOK is associated with 12 percentage point higher day care services coverage (details on request). A back of the envelope calculation suggests than a *HPTR* increase of 10,000 NOK would imply that one extra in eight pupils would have spent their pre-school years in a day care centre. If the superior performance of pupils exposed to the increase in school resources triggered by 10,000 NOK more in *HPTR* actually reflected day care centre attendance, spending time in these centres (rather than spending time home with their mother, typically) would have to raise the expected mark at age 16 by 1.5(!). An effect of about two standard deviations in the outcome distribution is beyond any reasonable impact. Cleary, the difference in child care coverage can only explain a minor fraction of the superior school performance at age 16 for pupils in *HPTR* communities. We also constructed data on day care centre quality based on the idea the employees with certified qualifications, i..e. 3-4 years of teritiary preschool teacher education, is a crucial component of care quality. When we calculated the number of employees with teritiary preschool teacher education as a fraction of children aged 1-6, by municipality we find no correlation with *HPTR*.

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

[20] 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).

As a final check, we included child care service coverage and quality as municipality controls in both stages of our IV estimation, see Table 12. Naturally, the power of the *HPTR* instrument drops a little and the day care coverage is positively correlated with school expenditures, see Panel A. Day care *quality*, however, is not significantly related to school spending. More importantly, the resource effects are basically unchanged and remain significant, even if the standard errors of the estimates increase slightly, see panel B Table 12.

7. Teacher hours

Increased spending on schools is reflected in more inputs. For policy purposes, it is useful to know whether higher expenditures facilitate performance due to more teacher input or e.g. better access to teaching techonology like computers, school books or less crowded rooms. We find that our instrument does affect the quantity of teacher input as the effect of *HPTR* on log teacher hours per pupil is estimated to be 0.065, see Table A1 in appendix. In other words, 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 than for total expenditures.

Turning to the effect on pupil outcomes, the IV estimate suggests that a 10% rise in teacher hours per pupil will cause an improvement in the average mark by about .254. Thus, 10% higher teacher hours will lift one in every four pupils up one level, see Table 13. More teacher presence or smaller groups do also affect pupils throughout the ability distribution as the effects on basic as well as high skills are both significantly positive. 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.

As school inputs are more than teachers, there is reason to believe that the teacher-hours-effect is inflated. Technically, the exclusion restriction does not hold when other inputs (e.g. computers, building facilities, teacher assistants etc) that raise pupil achievement are higher in *HPTR* municipalities. This reflects the more general identification problem; school inputs are multidimentional and it is hard to pin down the casual effects of each of them.

Notwithstanding the positive bias, our results certainly suggest that a teacher input effect is an important channel through which more resources raise pupil achievement.

8. Conclusions

Unobserved pupil heterogeneity and incomplete measures of school inputs make empirical identification of school input effects a challenge. Our approach is founded on the geographical location of natural resources and a set of institutional features in the educational sector in Norway that generate variation in school resources that is argued to be 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 expenditures on pupil performance at the age of 16 and find that higher spending does have a significantly positive effect on individual achievement. The IV regression indicates that NOK 10,000 (US$1,175) higher expenditures per pupil are estimated to raise the exam mark by 0.2. Thus, every fifth pupil will have his/her exam mark raised by one level on a 1 to 6 scale 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 0.25, 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 or family investments among pupils born in *HPTR* municipalities, 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, the supply and quality of day care services as an example of correlated amenities which are more widely available in *HTPR* municipalities, but these 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 and 2006 mathematics-performance examinations shows that between-school variation is low in Norway compared with what is found in other countries (see e.g. 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.

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Figures

Figure 1. Distribution of Predicted Expenditure, by HPTR.

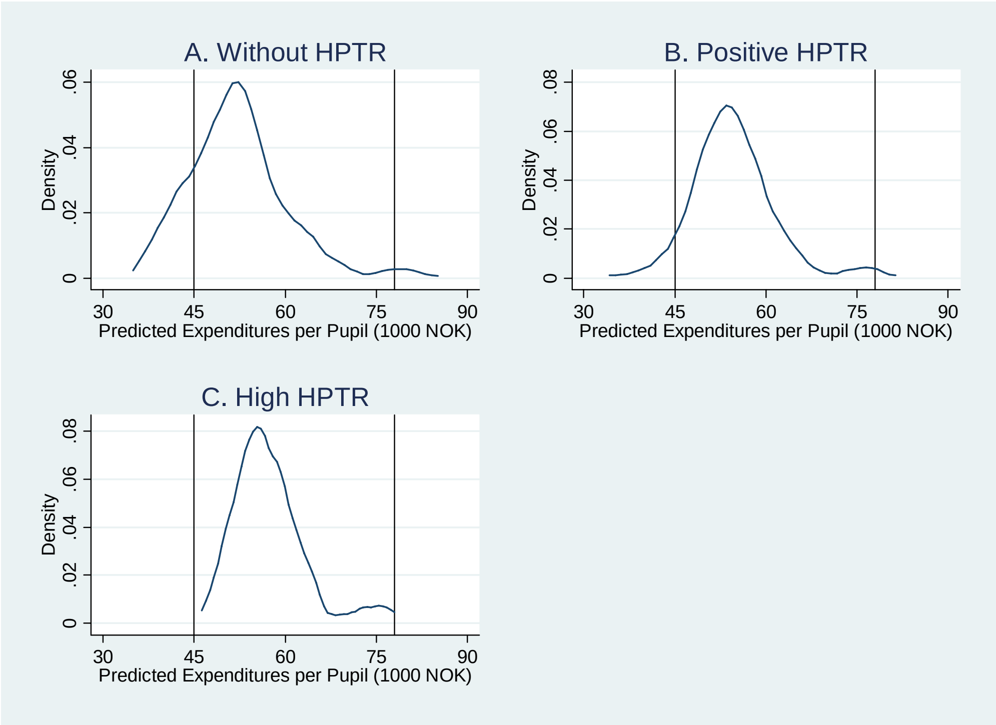


Figure 2. Geographical location of municipalities, by hydropower property tax revenue

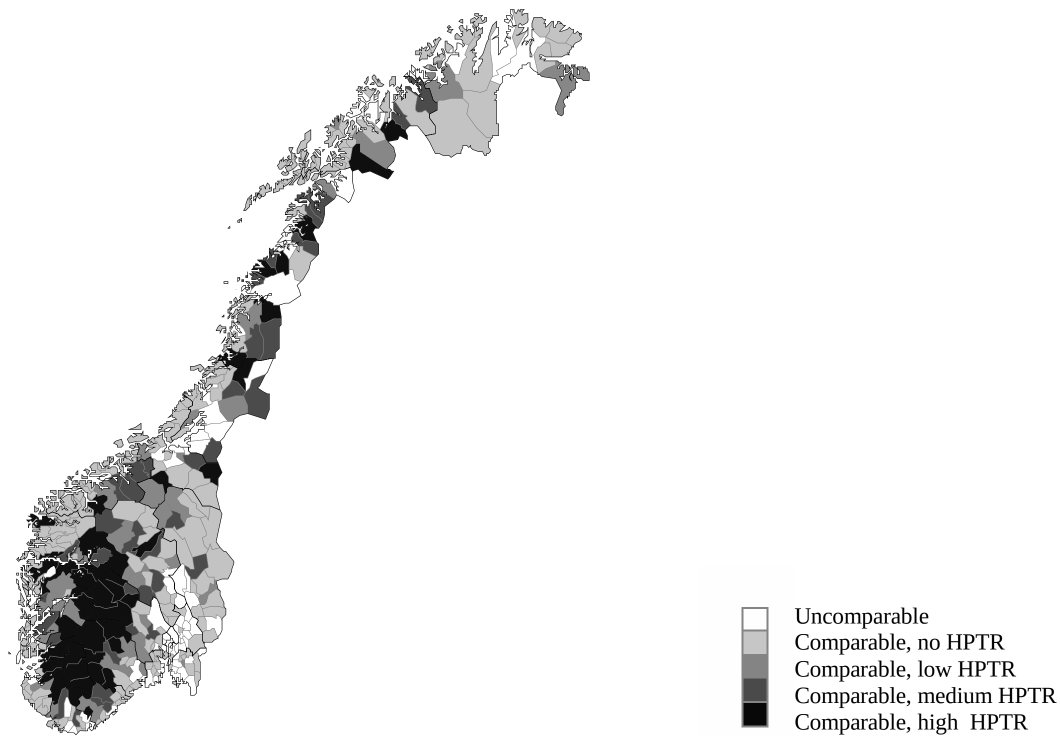
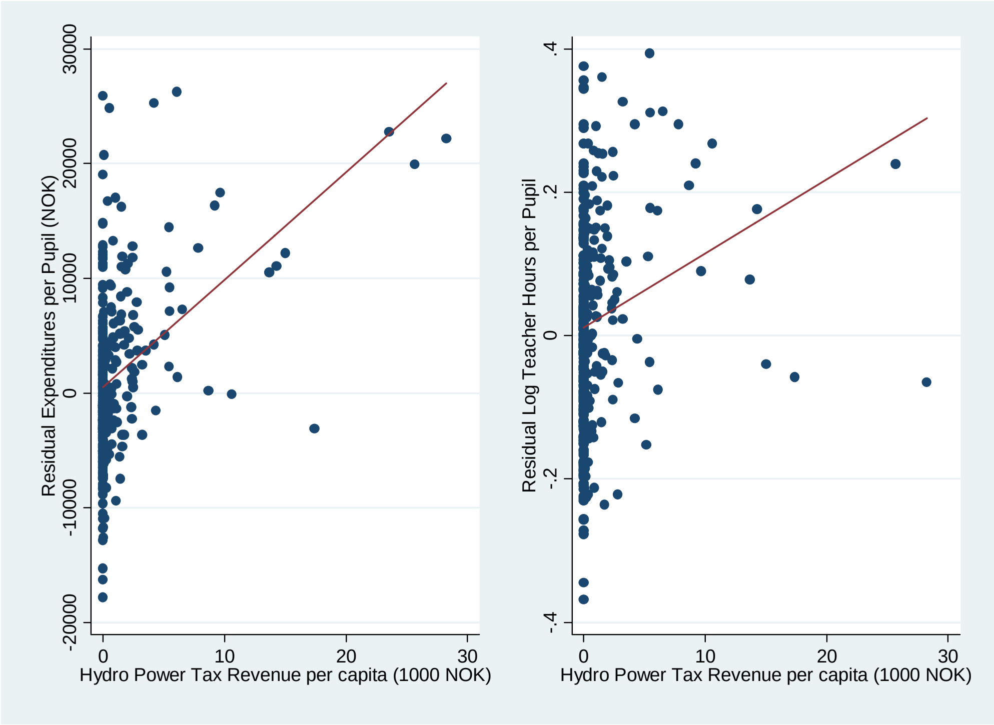


Figure 3. School resources and hydro power tax revenues



Tables

Table 1. Marks distribution, final written exam lower secondary school, *2003*

Mark	Percent
1	2.63
2	18.58
3	32.31
4	28.69
5	15.24
6	2.55
Mean	3.43
Standard deviation	1.11
# of pupils	51 483

Table 2. School expenditures, HPTR and municipality characteristics

	(1) All municipalities	(2) Municipalities without *HPTR*	(3) Comparable municipalities
A. Expenditures (NOK 10, 000)			
Average	5.43	5.21	5.52
Standard dev	1.11	1.03	.968
10^{th} percentile	4.39	4.28	4.52
90^{th} percentile	6.86	6.60	6.80
B. OLS			
Pupils/10000	-5.00 (.062)	-4.93 (.709)	–25.1 (3.40)
$Pupils^2/10^8$	4.77 (.73)	4.56 (.775)	122 (24.3)
$Pupils^3/10^{12}$	–1.10 (.19)	–1.03 (.199)	–190 (62.7)
Travelling distance (neighbour)	.146 (.021)	.144 (.026)	.075 (.025)
Travelling distance (zone)	.021 (.007)	.015 (.010)	.041 (.007)
Fraction mentally retarded	75 (60)	119 (79)	165 (53)
Political left majority	.061 (.090)	.125 (.125)	-.007 (.086)
Fraction tertiary education	2.59 (1.24)	3.39 (1.52)	–.966 (1.49)
Pupil composition, parental characteristics			
Fraction tertiary ed.	-.50 (.149)	.008 (.779)	-.276 (1.29)
Fraction upper secondary ed.	-.31 (.140)	.520 (.726)	.202 (.54)
Family earnings			
Fraction in quintile 1	–.17 (.514)	–.172 (.719)	.381 (.459)
Fraction in quintile 2	–.21 (.527)	.568 (.746)	-.204 (.482)
Fraction in quintile 4	.595 (.623)	1.34 (.772)	.473 (.594)
Fraction in quintile 5	–.48 (.765)	–.448 (.941)	.949 (.744)
Fraction unemployed	1.22 (.75)	2.52 (.966)	.776 (.694)
Fraction with disability pension	-.367 (.605)	–.253 (.761)	-.474 (.560)
Fraction on welfare benefits	-.683 (102)	-1.17 (1.34)	.030 (.934)
Fraction non-Western immigrants	1.07 (1.18)	1.57 (1.36)	1.14 (1.09)
HPTR per capita (NOK 10,000)	.92 (.120)		.81 (.011)
# Municipalities	424	295	344
# Pupils	50,283	42,279	21,423
Adj R^2	.628	.610	.653
Marg. Adj R^2	.054	Na	.059

Note: # of pupils (as a municipality characteristic) refers to 1^{st}–10^{th} grades. The 19 county fixed effects are not reported.

Table 3. School expenditures 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)	53,123	53,617	58,159	64,497
HPTR per capita (NOK)	0	402	1,290	6,797
Pupils in 1st–10th grades	801	830	514	376
Travelling distance (neighbour)	3.59	3.24	4.24	5.08
Travelling distance (zone)	8.11	8.57	10.21	11.28
Left majority	.226	.318	.324	.250
Fraction tertiary education	.160	.168	.146	.157
Fraction mentally retarded, 6–15	.0007	.0006	.0007	.0006
Pupil composition, parental characteristics				
Fraction with tertiary education	.308	.317	.289	.317
Fraction with secondary education	.637	.649	.667	.635
Family earnings				
Fraction in quintile 1	.213	.225	.266	.256
Fraction in quintile 2	.258	.255	.282	.272
Fraction in quintile 4	.177	.183	.144	.145
Fraction in quintile 5	.095	.087	.074	.075
Fraction unemployed	.064	.044	.064	.048
Fraction with disability pension	.098	.114	.118	.099
Fraction on welfare benefits	.033	.028	.043	.040
Fraction non-Western immigrants	.021	.019	.022	.014
# Municipalities	225	38	37	44

Note: Sample of municipalities with comparable (predicted) expenditures per pupil. Expenditure per pupil refers to 1st–10th grades last three years.

Table 4. 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						
	53,618	52,395	58,160	53,461	64,497	55,885
B. Municipality characteristics						
HPTR per capita	.403	0	1,280	0	6,797	.0
# pupils	831	823	514	665	376	521
Travelling distance (neighbour)	3.25	3.56	4.24	3.85	5.08	4.21
Travelling distance (zone)	8.58	7.69	10.21	8.34	11.28	9.16
Political left majority	.316	.126	.324	.200	.250	.250
Fraction tertiary education	.168	.159	.146	.159	.157	.154
Fraction mentally retarded	.0006	.0007	.0007	.0008	.0006	.0007
Pupil composition, parental characteristics						
Fraction with tertiary education	.317	.303	.289	.288	.317	.291
Fraction with sec. education	.649	.654	.667	.641	.634	.631
Family earnings						
Fraction in quintile 1	.225	.203	.266	.218	.256	.214
Fraction in quintile 2	.255	.262	.282	.278	.272	.278
Fraction in quintile 4	.183	.174	.144	.174	.146	.172
Fraction in quintile 5	.096	.100	.074	.091	.075	.079
Fraction unemployed	.044	.060	.064	.062	.048	.069
Fraction with disability pension	.114	.096	.118	.095	.099	.095
Fraction on welfare benefits	.028	.030	.043	.033	.040	.034
Fraction non-Western immigrant	.019	.017	.022	.019	.014	.018
# Municipalities	38	38·5	37	37·5	44	44·5

Table 5. School expenditures and pupil performance: Wald estimates based on neighbouring municipalities.

	Marks Differential	Wald Estimates (NOK 10,000)
	I. Mean (on scale 1 to 6)	
HPTR > 0 vs no	.051*	.110*
	(.027)	(.059)
Low *HPTR* vs no	-.020	-.136
	(.045)	(.310)
Med *HPTR* vs no	.032	.071
	(.033)	(.076)
High *HPTR* vs no	.158***	.185***
	(.051)	(.057)
	II. Basic skills (proportion with mark > 2)	
HPTR > 0 vs no	.014	.029
	(.010)	(.020)
Low *HPTR* vs no	.003	.027
	(.016)	(.143)
Med *HPTR* vs no	.006	.013
	(.015)	(.031)
High *HPTR* vs no	.035*	.038*
	(.018)	(.021)
	III. High skills (proportion with mark 5 or 6)	
HPTR > 0 vs no	.022**	.045**
	(.011)	(.022)
Low *HPTR* vs no	-.008	-.044
	(.017)	(.091)
Med *HPTR* vs no	.015	.030
	(.011)	(.024)
High *HPTR* vs no	.078***	.080***
	(.020)	(.020)

Note: Wald estimates based on (Mean Differential Performance/Mean Differential Expenditures). Performance is adjusted for individual pupil family background. Resource differentials are displayed in Table 3. Standard errors are in parentheses. In column (2), */**/*** 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 6. School expenditures 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
Effect of increased expenditures (NOK 10,000) per pupil on				
I. Mean	.017 (.016)	.040** (.014)	.015 (.023)	.219*** (.066)
II. Basic skills	.002 (.005)	.009 (.005)	–.005 (.007)	.055*** (.019)
III. High skills	.003 (.005)	.007 (.005)	.002 (.008)	.048** (.021)
Family characteristics	No	Yes	Yes	Yes
Municipality controls	No	No	Yes	Yes
# Municipalities	344	344	344	344

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. School expenditures 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
Effect of increased expenditures (NOK 10,000) per pupil on				
I. Mean	.003 (.012)	.031 (.011)***	.018 (.017)	.179 (.048)***
II. Basic skills	.003 (.004)	.010 (.004)**	–.002 (.005)	.043 (.014)**
III. High skills	.000 (.004)	.007 (.004)	.003 (.006)	.040 (.015)**
Family characteristics	No	Yes	Yes	Yes
Municipality controls	No	No	Yes	Yes
# Municipalities	424	424	424	424

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 8. Unobserved family investments. Associations between HPTR (10, 000 NOK) and pupil (municipality fixed) endowments in terms of Birth Weight, Head Size and Apgar Score.

	All municipalities	Comparable municipalities
Birth weight (ln kg)	-.0006	-.0007
	(.0008)	(.0008)
Head size (cm)	-.0015	.0053
	(.0097)	(.0088)
Apgar 5 score	-.0073	-.0132
	(.0109)	(.0081)
# Individual pupils	41,830	16,964
# Municipalities	424	344

Note: Apgar score is from the general test of a child health on a scale from 1-9 here measured 5 minutes after birth. 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 Municipality level controls: All variables included in the IV estimates, see Table 4

Table 9. Pupil seniority in graduation municipality. Per cent.

	Comparable municipalities	All municipalities	Municipalities with *HPTR* > 0
Less than 3 years	4.9	4.9	4.1
4–6 years	4.6	4.7	3.9
7–10 years	7.0	7.6	6.0
11–15 years	16.1	17.2	15.6
16 years (Born in municipality)	67.4	65.6	70.4

Table 10. Mobility and observed family background; Effects on the probabilities of graduation in high or medium level HPTR municipalities

	All pupils	*Pupils who moved during 1989–2002*
Predicted mark	-0.085	-0.242
	(0.005)***	(0.014)***
Born in municipality with		
Low HPTR	0.010	0.052
	(0.003)***	(0.011)***
Medium HPTR	0.767	0.096
	(0.014)***	(0.021)***
High HPTR	0.808	0.104
	(0.013)***	(0.024)***
Pseudo R^2	0.655	0.111
# pupils	47,691	11,437

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

Table 11. Alternative sample definitions: Comparable municipalities.

	(1) Pupils born in Norway by Norwegian parents	(2) Pupils born in graduation municipality	(3) Municipality of graduation replaced by municipality of birth	(4) Sample restricted to first-born children	(5) Sample restricted to first-born children Municipality of graduation replaced by municipality of birth
			I. Mean		
Wald	0.184 (0.058)***	0.210 (0.060)***	0.174 (0.055)***	0.154 (0.066)**	0.088 (0.062)
OLS	0.017 (0.016)	0.020 (0.018)	0.006 (0.022)	-0.001 (0.028)	-0.005 (0.029)
IV	0.216 (0.066)***	0.215 (0.072)***	0.170 (0.059)***	0.172 (0.073)**	0.116 (0.077)
			II. Basic skills		
Wald	0.035 (0.018)*	0.035 (0.024)	0.050 (0.025)*	0.057 (0.031)*	0.059 (0.032)*
OLS	0.001 (0.005)	-0.004 (0.006)	-0.004 (0.007)	-0.006 (0.009)	-0.006 (0.009)
IV	0.053 (0.019)***	0.065 (0.023)***	0.046 (0.018)***	0.028 (0.021)	0.011 (0.023)
			III. High skills		
Wald	0.080 (0.021)***	0.084 (0.019)***	0.054 (0.017)***	0.048 (0.019)**	0.034 (0.018)*
OLS	0.003 (0.005)	0.007 (0.005)	0.007 (0.006)	-0.003 (0.009)	0.006 (0.009)
IV	0.048 (0.021)**	0.047 (0.024)**	0.036 (0.015)***	0.024 (0.021)	0.025 (0.022)
# pupils	20,625	14,554	19,641	9,604	8,569

Note: Dependent variables are average marks (I), Fraction with basic skills (II) and high skills (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 12. Day care, HPTR and school resource effects.

	All municipalities	Comparable municipalities
	A. Coefficients in the expenditure equation (stage 1)	
HPTR per capita (NOK 10,000)	0.067 (0.012)***	0.072 (0.012)***
Day care coverage	1.855 (0.325)***	0.932 (0.358)***
Day care quality (certified pre-school teachers per child in daycare)	2.184 (1.565)	1.795 (1.650)
	B. Expenditure-effect on mean with day care coverage and quality controls	
OLS	-0.004 (0.020)	0.002 (0.024)
IV	0.233 (0.084)***	0.239 (0.085)***
# Municipalities	408	339

Note: Coverage and quality measured defined in the text. The number of municipalities is slightly lower here than in Table 5 and 6 due to missing data on child care variables. However, the results in Table 5 and 6 are basically unchanged if we restrict the sample to the municipalities represented in this table.

Table 13. Teacher hours and pupil performance; Comparable municipalities: OLS and IV estimates. Effect of more teacher hours (ln(hours per pupil)/10)

	(1) OLS No controls	(2) Family background adjusted OLS	(3) Family background adjusted + municipality characteristics. OLS	(4) IV
	Panel A. Comparable municipalities			
I. Mean	.001 (.006)	.015*** (.006)	.002 (.011)	.254** (.111)
II. Basic skills	.000 (.002)	.004** (.002)	–.002 (.003)	.059** (.027)
III. High skills	.001 (.002)	.004* (0.002)	.002 (.004)	.041* (.024)
	Panel B. All municipalities			
I. Mean	–.001 (.005)	.015*** (.005)	.010 (.008)	.150*** (.052)
II. Basic skills	.002 (.002)	.006*** (.001)	.003 (.003)	.033*** (.012)
III. High skills	-.001 (.002)	.004** (.002)	.003 (.003)	.033** (.014)
Family characteristics	No	Yes	Yes	Yes
Municipality controls	No	No	Yes	Yes
# Municipalities	355/424	355/424	355/424	355/424

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.

Appendix

Table A1. Teacher hours, HPTR and municipality characteristics

	(1) All municipalities	(2) Municipalities without *HPTR*	(3) Comparable municipalities
	Panel A. Descriptive statistics		
Average	4.53	4.50	4.55
Standard dev	.25	.25	.22
10^{th} percentile	4.26	4.25	4.30
90^{th} percentile	4.89	4.89	4.87
	Panel B. OLS		
Pupils/10000	–1.24 (.13)	–1.20 (.016)	–6.74(.761)
$Pupils^2/10^7$	11.2 (1.51)	10.5 (1.71)	3.48(.575)
$Pupils^3/10^{12}$	–25.1 (3.95)	–23.0(4.38)	–56.4 (11.9)
Travelling distance (neighbour)	.034 (.004)	.040 (.0056)	.016 (.005)
Travelling distance (zone)	.001 (.001)	-.002 (.002)	.005 (.001)
Fraction mentally retarded	.28 (13)	14 (17)	18 (11)
Political left majority	-.006 (.019)	.006 (.028)	-.006 (.017)
Fraction tertiary education	.280 (.267)	.545 (.334)	.001 (.260)
	Pupil composition, parental characteristics		
Fraction tertiary ed.	–.143 (.138)	–.205 (.172)	–.021 (.121)
Fraction upper secondary ed.	–.128 (.130)	–.109 (.334)	–.099 (.115)
Family earnings			
Fraction in quintile 1	–.023(.110)	–.139 (.158)	-.016 (.096)
Fraction in quintile 2	–.059 (.113)	–.064 (.164)	-.103 (.100)
Fraction in quintile 4	–.046 (.242)	–.077 (.170)	-.136 (.120)
Fraction in quintile 5	–.023 (.164)	–.041 (.207)	.111 (.153)
Fraction unemployed	.696 (.164)	.784 (.213)	.499 (.145)
Fraction with disability pension	–.034 (.130)	.074 (.168)	-.001 (.121)
Fraction on welfare benefits	-.123 (.220)	–.182(.295)	-.092 (.197)
Fraction non-Western immigrants	.483 (.254)	–.455 (.300)	–.436 (.225)
HPTR per capita (NOK 10,000)	.100 (.026)		.073 (.025)
# Municipalities	424	295	355
# Pupils	50,235	42,279	23,336
Adj R^2	.654	.638	.710
Marg. Adj R^2	.012	Na	.012

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. The 19 county fixed effects not reported.

Table A2. 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					
	89.84	89.66	109.00	100.38	110.76	99.80
	B. Municipality characteristics					
HPTR per capita	392	.0	1,269	.0	6,407	.0
# pupils	1061	894	496	578	378	527
Travelling distance (neighbour)	3.14	3.16	4.38	4.12	5.09	4.15
Travelling distance (zone)	8.24	7.39	10.75	9.86	11.28	9.43
Political left majority	.390	.171	.351	.216	.256	.164
Fraction tertiary education	.172	.161	.145	.154	.156	.154
Fraction mentally retarded	.0006	.0008	.0007	.0008	.0006	.0007
	Pupil composition, parental characteristics					
Fraction with tertiary education	.324	.314	.291	.297	.318	.299
Fraction with sec. education	.641	.634	.665	.639	.635	.649
Family earnings:						
Fraction in quintile 1	.223	.200	.264	.211	.242	.217
Fraction in quintile 2	.250	.248	.286	.275	.272	.276
Fraction in quintile 4	.185	.185	.144	.167	.147	.169
Fraction in quintile 5	.091	.110	.073	.084	.077	.083
Fraction unemployed	.045	.051	.068	.069	.049	.063
Fraction with disability pension	.113	.095	.118	.086	.100	.093
Fraction on welfare benefits	.029	.029	.044	.029	.041	.031
Fraction non-Western immigrant	.020	.024	.021	.017	.014	.015
# Municipalities	41	41*5	37	37*5	41	41*5

Table A3. Alternative sample definitions: Teacher hours effects Comparable municipalities.

	(1) Pupils born in Norway by Norwegian parents	(2) Pupils born in graduation municipality	(3) Municipality of graduation replaced by municipality of birth	(4) Sample restricted to first-born children	(5) Sample restricted to first-born children Municipality of graduation replaced by municipality of birth
	I. Mean				
Wald	0.080	0.095	0.072	0.087	0.038
	(0.048)	(0.055)*	(0.047)	(0.054)	(0.051)
OLS	0.001	-0.001	0.003	0.000	-0.009
	(0.011)	(0.015)	(0.010)	(0.013)	(0.013)
IV	0.251	0.278	0.177	0.209	0.114
	(0.110)**	(0.130)**	(0.083)**	(0.096)**	(0.077)
	II. Basic skills				
Wald	0.009	-0,002	0.015	0.053	0.062
	(0.016)	(0.017)	(0.022)	(0.036)	(0.048)
OLS	-0.002	-0.003	-0.002	-0.001	-0.005
	(0.003)	(0.004)	(0.003)	(0.004)	(0.004)
IV	0.062	0.069	0.049	0.034	0.015
	(0.028)**	(0.032)**	(0.026)*	(0.023)	(0.021)
	III. High skills				
Wald	0.043	0.053	0.032	0.024	0.017
	(0.016)***	(0.019)***	(0.014)**	(0.012)**	(0.014)
OLS	0,.003	0.004	0.005	0.002	0.004
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
IV	0.040	0.050	0.042	0.018	0.016
	(0.024)*	(0.028)	(0.025)*	(0.020)	(0.021)
# pupils	22,451	15,693	21,265	10,942	9,441

Note: Dependent variables are average marks (I), Fraction with basic skills (II) and high skills (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.