The Long-Run Impact of School Funding on Economic Outcomes

Daniel Duque*
Norwegian School of Economics (NHH)

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Abstract

This paper provides a comprehensive assessment of the impact of education finance on students' long-term outcomes and the mechanisms through which these effects operate. For identification, I exploit an intergovernmental transfer reform in Norway, which generated exogenous variation in school funding based on the school-aged demographic composition at the local level in the mid-1980s. The main takeaway is that exposure to an additional $100 per pupil in education funding over nine years of primary and lower-secondary school leads to nearly $250 in higher annual earnings. This effect corresponds to an Internal Rate of Return (IRR) greater than 6% and a Marginal Value of Public Funds (MVPF) ranging from 1.5 to 2.5. The increase in earnings is mediated by higher educational attainment, higher likelihood of obtaining a degree in high-paying fields, and improved cognitive abilities. The effect is larger and more significant for students from low-educated parents and those at the lower end of the earnings distribution, while no significant impact is found for students with at least one college-educated parent. At the municipal level, the funding shock led to an increase in teacher hiring without affecting capital expenditures.

JEL Classification: H75, I21, I26, I28

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*Contact information: daniel.duque@nhh.no.
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1 Introduction

Education is a crucial factor for individual and societal advancement. For individuals, it is linked for example to higher earnings [Devereux and Fan, 2011], more employment [Riddell and Song, 2011], and lower mortality [Balaj et al., 2024]. For society, it is associated with higher productivity [Kampelmann and Rycx, 2012], higher voter turnout [Sondheimer and Green, 2010], and greater social mobility [Lindley and Machin, 2012]. Given these benefits, countries are constantly trying to improve their education systems, and one of the most straightforward ways to do this is through funding. This has been the subject of considerable academic and policy debates over the last several decades, and there are still many uncertainties. Unveiling the long-term effects of school funding, particularly on earnings, is challenging due to the limited availability of data and exogenous shocks that impact students over long periods of time.

I overcome these limitations by leveraging an intergovernmental transfer reform that took place in the mid-1980s in Norway. By exploring a quasi-random shock to education funding, caused by a change in grant criteria based on the pre-reform age composition of students, I present detailed evidence of the long-term effects on individual outcomes once students are fully integrated into the labor market. By combining comprehensive municipal data with rich population-wide longitudinal data from Norwegian registers, I examine the impacts on individual outcomes such as educational attainment and earnings throughout adulthood, as well as distributional and heterogeneous effects.

Broad intergovernmental transfers (public grants) correspond to a large share of municipal expenditure on education. In 1986, one of the grant criteria, which differentiated revenue levels transferred to municipalities based on the composition of primary and lower-secondary school students, was removed. This change led local governments with a higher share of primary school students (relative to the total number of compulsory school students) to experience a relative increase in education funding. I take advantage of an event-study and a differences-in-differences design to examine the timing of the shock and its effect over time. Conditional on my controls for confounding shocks and fixed effects for municipality and cohort-by-year, my estimates are plausibly exogenous for the main assignment variable — specifically, the ratio of primary to compulsory school students prior to the reform.

I estimate the grant shock of the reform through cross-municipality variations in the demographic distribution of students aged 7 to 12 (primary school students) compared to those aged 7 to 15 (compulsory school students). This allows me to quantify the the shock size, in order to provide an assessment of the implications of additional transfers for education on short- and long-run outcomes.

Leveraging this policy change and estimating the grant shock, I investigate the impact on students who were exposed to additional $100 in school funding, and how the municipalities used this revenues on education spending and school inputs. I show that students who were at the right age to be in compulsory school, who were living in municipalities that received higher educational funding in the year prior to the reform, showed higher educational attainment and labor income by the age of around 35 years old. These results are conditional on standard individual characteristics likely to affect later-life outcomes, such as gender and parental education.

First, I show that an additional $100 in education funding led to an increase in the number of teachers. However, the funding did not affect class size, suggesting that the additional teachers and staff were mainly used to increase instructional intensity.

Second, I find that students exposed to the funding shock benefited substantially in the labor market. Specifically, an additional $100 in school funding led to nearly $250 higher annual earnings by ages 33–35. The earnings effect grows over time, starting near zero at ages 26–27 and peaking at ages 32–35. The magnitude of these results remains consistent across specifications.

Additionally, students exposed to the funding increase exhibit significant improvements in educational attainment by age 35, including an average increase of 0.03 years of schooling and a higher likelihood of obtaining a college diploma, particularly in STEM, law, business, or medicine. The size of these effects is comparable to the range found by Jackson and Mackevicius [2023], though slightly lower, likely due to the use of intention-to-treat estimates. Overall, the expected wage conditional on educational paths explains about one-third of the total earnings effect. Cognitive abilities also show a modest increase.

Since average effects may conceal substantial heterogeneity, I explore distributional impacts. The earnings effects are significantly larger at the lower end of the distribution, and both labor income and educational attainment effects are greater for students from low-educated families. For students with at least one college-educated parent, the effect of additional school funding on earnings is not statistically significant.

Given the broad and detailed impacts on later-life earnings, I conduct a cost-benefit analysis of increased education funding. The Internal Rate of Return (IRR) is estimated by comparing the costs—including the direct funding increase and its effect on additional educational attainment—against the increase in lifetime earnings from ages 28 to 60. By discounting future earnings and costs to estimate present values, I find that the benefits outweigh the initial and subsequent educational investments up to a discount rate of 6.2%. The IRR is particularly high for students from low-educated families, reaching approximately 8%.

Using the Marginal Value of Public Funds (MVPF) framework, I find that for a discount rate between 3% and 5%, the MVPF ranges from 1.5 to 2.5. However, for students whose parents had only compulsory schooling, the MVPF ranges from 2 to 3.5. These findings underscore the policy's effectiveness in promoting economic mobility and increasing lifetime earnings, supporting the case for increased educational investment.

For robustness checks, I confirm that the funding increase did not lead to higher spending in other major municipal sectors, making it unlikely that the shock was correlated with any policy other than education. Additionally, I narrow the age brackets to isolate potential spurious correlations with demographic composition, and the results remain consistently significant.

This paper connects two contrasting strands of literature: school input interventions with mixed effects and the positive impacts of school spending reforms in the U.S. By analyzing the effects of a significant funding shock, the findings reveal that schools used the additional funds to enhance teaching resources—such as increasing the number of teachers and instructional hours—without altering the composition of capital and current expenditures. This suggests that schools and municipalities may have a better understanding of how to allocate resources efficiently than previously thought, demonstrating that even in high-spending contexts, increased funding can yield positive results when strategically deployed.

In addressing the effects of education spending, existing literature—predominantly from the U.S.—has focused on school funding formula reforms since the 1970s [Jackson and Mackevicius, 2023; Baron, 2022]. There is substantial evidence documenting the impact of education spending on various outcomes, such as test scores [Card and Payne, 2002], educational attainment [Hyman, 2017; Jackson et al., 2021], wages [Jackson et al., 2015], poverty [Lafortune et al., 2018], and intergenerational mobility [Biasi, 2023]. However, most of this literature lacks detailed information on long-term monetary outcomes, focusing instead on immediate educational achievements or using income data from surveys.

This paper contributes by providing robust long-term estimates of increased school funding's impact on earnings, educational paths, and cognitive abilities. Using population-wide register data, I explore both distributional effects and policy cost-effectiveness, particularly for students from disadvantaged backgrounds.

Furthermore, research outside specific states in the U.S. is notably limited, often concentrating on capital expenditures, which may not be directly comparable due to differing methodological approaches [Belmonte et al., 2020; Gibbons et al., 2017; Heinesen and Graversen, 2005]. This study bridges these gaps by examining the long-term effects of increased educational funding on students' earnings into adulthood within a broader international context. Although Norway's education system is well-funded and structured differently from that of the U.S., it presents a valuable comparative analysis of how varying levels of educational investment impact long-term economic outcomes.

This paper also adds to the literature examining local government responses to central government grants, offering insights into their impact on educational funding and outcomes. The literature has shown mixed results, ranging from significant crowding out to increased local spending and improved educational outcomes [Gordon, 2004; Cascio et al., 2013; Litschig and Morrison, 2013]. Considering other revenue shocks for education, this paper is related with Brunner et al. [2022], that found that school districts used additional revenue, due to installation of wind turbines, mostly on capital spending, which led to zero effects on students' long-run outcomes. This paper finds mainly effects on operational expenditures, with municipalities increasing both the number of teachers, and no effect on capital spending.

Finally, this study contributes to the debate on the effect of school inputs on learning and long-term outcomes. While most research focuses on class size, generally finding positive impacts [Angrist and Lavy, 1999; Fredriksson et al., 2013], evidence from Norway presents a mixed picture [Leuven and Løkken, 2020; Borgen et al., 2022]. This paper shows that, while class sizes remained unchanged, teacher hiring seems to be driving the long-run positive effects on students.

2 Institutional Background

2.1 Educational System in Norway

Norway consistently ranks among the top countries for public education spending, with expenditures as a share of GDP increasing from nearly 6% in the 1980s to about 7% in subsequent decades. Despite a decreasing proportion of school-age children, per-student spending has remained stable at about 20% of GDP per capita, placing Norway among the top 10 countries in spending relative to this educational level.

Education in Norway is free from primary through tertiary levels. Municipalities manage primary and lower-secondary education for children aged 7 to 15, while counties handle upper-secondary education, which has an enrollment rate of around 90%. The National Ministry of Education and Research oversees higher education, where enrollment rates surged from 25% to 80% after 2000.

Norwegian schools are characterized by small sizes and low student-to-teacher ratios, enhancing individual attention, although educators generally earn less than their similarly educated peers in other sectors. Municipalities have autonomy over resource distribution, and schools have some discretion in budget and staffing decisions, but they remain under national regulations set by the Ministry of Education and Research.

Educational assessments in Norway begin in lower-secondary school, with high-stakes testing limited to the final years of lower-secondary and upper-secondary levels. Since 2004, national tests have been used to foster school improvement and support students needing additional help. On international benchmarks like the Programme for International Student Assessment (PISA)[1], Norway performs well in reading and mathematics across socio-economic groups. However, despite high spending, challenges remain in closing performance gaps and improving teacher salaries and professional development [OECD, 2020].

2.2 Intergovernmental transfers up to 1985

During the 1960s and 1970s, municipal revenues increased steadily, mostly funded by intergovernmental transfers and reimbursement schemes. By the early 1980s, the Central Administration was responsible for funding around 35% of municipal spending, which is similar to levels seen in most developed countries with decentralized government systems [Bergvall et al., 2006]. Municipal tax revenues, on the other hand, made up 60% of municipalities' budgets.

The autonomy of municipalities in Norway was gradually reduced by the central government in the post-war years due to the political objective of universal welfare services. However, Langørgen et al. [2013] documents that the revenue system of the municipalities became increasingly complex, consisting of many small and large earmarked grants that lacked incentives for cost efficiency.

Regarding intergovernmental transfers for education, regulations in place until 1985 required the Central Administration to cover between 25% and 85% of each municipality's gross expenses on the sector. The transfer amount was calculated based on the number of teaching hours, which were valued differently depending on the level of education (Cost Factor). Other minor criteria were also used to determine smaller portions of the transfer, such as per capita municipal tax revenues and the share of education spending in total municipal expenditure. The formula for the transfer is given by the following:

$$Transfer_{m,t} = \sum_{l} (\text{Cost Factor}_{l,t} \times Hoursl, m, t) + \epsilon_{l,m,t},$$

where $Transfer_{m,t}$ represents the transfer amount to municipality m for grant size in year t, Cost Factorl, t represents the Cost Factor at the schooling level l in year t, $Hoursl, m, t$ represents the annual teaching hours at level l in municipality m set in year t, and $\epsilon_{l,m,t}$ represents the sum of the other criteria (per capita municipal

[1]A triennial international survey which aims to evaluate education systems worldwide by testing the skills and knowledge of 15-year-old students.

tax income, the share of education spending in total municipal expenditure, etc.) at level l in each municipality m set in year t.

The Cost Factor was determined by the Central Government each year for primary and lower-secondary levels separately. In 1985, the Cost Factor was set at NOK 130.05 ($29.30 in 2011 PPP dollars) for primary education (for children aged 7 to 12) and NOK 146.80 ($33.07 in 2011 PPP dollars) for lower-secondary education (for children aged 13 to 15).

Municipalities could determine the number of weekly hours pupils received from 1st to 6th grade within a range of 129 to 147 weekly teaching hours, with the Central Administration grants covering up to 138 hours, plus 10% for special education. At the lower-secondary level, the number of weekly hours was set at 30 for regular teaching at each grade level, in addition to 17.5 hours per week for special education, electives, and other measures.

2.3 The 1986 intergovernmental transfers reform

In 1979, the Norwegian Tax Equalization Committee released a report proposing a new intergovernmental transfer system for counties[2], and in 1982, a similar report was released for municipalities[3]. These reports served as the basis for the bills that introduced a new system in 1986, replacing most prevailing intergovernmental grants[4], creating an income-equalizing grant and three major sector grants for health, education, culture, and general purposes.

For each sector, cost matrices were constructed based on characteristics that counties and municipalities could not change over time. Associated weights were applied to these variables, providing a number of "points," which are used to distribute central administration grants to this day. The criteria and weights were developed to address the varying costs municipalities face in delivering an equal range of services in each of the three sectors.

Under this new set of rules, in the education cost matrix, no distinction was made between primary and lower-secondary education, as shown in Table 1. As a result, municipalities with a higher proportion of younger children (aged 7 to 12) experienced an exogenous increase in the grant transfer amount.

[2] NOU 1979: 44

[3] NOU 1982: 15

[4] St.meld. No. 26 (1983-84) - "On a new revenue system for the municipalities and counties", and Ot.prp. No. 48 (1984-85) - "On amendments to laws concerning the revenue system for the municipalities and counties"

Table 1: Primary Education Cost Matrix

Criteria	Weight
Approved annual teaching hours in 1985	0.47
Number of inhabitants 7-15 years	0.41
Others	0.12

Source: Langørgen et al. [2013]

It was emphasized that the transition to the new system in 1986 would not lead to major changes in transfers to local administrations in the short term. Changes in criteria and weights were to be phased in over several years: in the first two years, the new system would be weighted at 10% and 20%, respectively, while the old system would account for the higher share. In 1988, however, the previous year's level was weighted at 80%, and the new rules were fully incorporated in 1989.

3 Data and Methodology

The analysis uses several registry databases maintained by Statistics Norway. The sample is restricted to municipalities that did not merge, split, or change their borders between 1980 and 1991, which corresponded to 402 out of the total 456 municipalities. This restriction ensures that I consistently classify municipalities over time.

For fiscal data, the Strukturtall for kommunenes økonomi documents are used, which are available on the Statisk Sentralbyrå (SSB) website. These documents provide detailed data on municipal per capita gross and net operating expenses since 1974. Municipal-level demographic and education-related variables, such as the number of students, schools, and teachers, are provided by the kommunedatabasen, which covers a wide range of municipality characteristics and policies since the early 1970s.

At the individual level, the sample includes all individuals born between 1964 and 1983 who were living in any of those 402 municipalities in 1985 and in any municipality in Norway by the age of 35. The sample size is approximately 1.1 million individuals, of whom around 995,000 had a paying job.

This study explores the effect of the policy on earnings at ages 33 to 35 and educational attainment, as Haider and Solon [2006] and Böhlmark and Lindquist [2006] show that the association between lifetime returns to schooling and current earnings is strongest by the mid-30s. Since earnings increases capture only individuals' monetary output, I also investigate the outcomes mediating this economic effect.

First, the impact of education funding on earnings is also mediated by educational level and field of study. To assess this channel, I use the educational levels and 2-digits groups of degrees, as defined by the Norwegian Central Statistical Bureau, which are listed in the appendix. One of the outcomes using this classification is the likelihood of holding a tertiary education degree of STEM, law, business or medicine, wich is denominated as STEM+.

Additionally, I employ a predictive model focusing on the wages of individuals aged 33 to 35 based on all levels of educationa and their 2-digits groups of degree. The adapted Mincerian wage equation includes cohort and municipal fixed effects. The education-specialization categories are compared to a baseline category representing only compulsory education. Using predicted $E(Y|\text{Education-Specialization}_{k,i})$ as an outcome, I assess the effects of educational funding on earnings through educational level and field of study, further identifying the channels through which the overall policy affects income.

Higher human capital potentially translates into cognitive abilities [Ritchie and Tucker-Drob, 2018], but, until the early 2000s, no data on grades or cognitive/non-cognitive abilities was available for the entire population. Thus, I use military conscription register data at ages 18–19 for the vast majority of Norwegian-born males. During the recruitment process, most young men were required to take the General Ability Test (GAT) to evaluate their suitability for military service. The GAT consists of three speeded tests of arithmetic (30 items), word similarities (54 items), and figures (36 items). About 6-9% of the 1977-81 cohorts did not take the test due to various unrecorded reasons, such as severe physical or mental disabilities.

The GAT is similar to the AFQT and the Wechsler IQ test. Standardized component scores are reported on a 1-9 stanine scale, where category 5 represents an average IQ of 100, and one stanine unit equals a difference of 7.5 IQ points. Following convention, I calculate the IQ score from the aggregate stanine score given to each conscript. Apart from the mathematics test changing to a multiple-choice format in the early 1990s, both the test and the scoring norm remained constant throughout the period.

A third channel explored is migration choices. The literature highlights that local educational investments also affect individuals seeking better labor market opportunities [Kline and Moretti, 2014; Shapiro, 2006]. From a municipal perspective, this effect could be a partial drawback, as the migration of students who benefited from additional funding may reduce the local gains in earnings. This "brain drain" effect is particularly pronounced in settings where disparities in economic opportunities are significant across regions.

Therefore, I investigate the phenomenon of "brain drain" by examining the longitudinal effects of school funding on migration across different life stages. Specifically, I focus on early adulthood (21-23 years), late twenties (27-29 years), and mid-thirties (33-35 years) to understand how increased educational opportunities influence migration decisions over time. The outcome variables include the probability of living in a different municipality from the one where the individual resided in 1985 or living in a large city[5].

3.1 Descriptive Statistics

Education spending accounted for around 29% of municipal expenditures between 1980 and 1985, while tax revenues made up only 45% of total municipal revenues. Table 2 shows the trends in some key variables.

Table 2: Municipal-Level Sample Averages

Year	(1) Yearly Expenditure on Education	(2) Share of Primary and Lower-Secondary School Students over Population	(3) Share of Primary School Students over (2)	(4) Public Schools	(5) Students per Teacher	(6) Teaching Hours Per Pupil Proxy	(7) Class Size
1981	5797.5	0.152	0.659	7.69	10.96		18.67
1982	5912.5	0.150	0.651	7.71	10.79		18.54
1983	6050.4	0.148	0.646	7.72	10.62	4.38	18.43
1984	6209.3	0.144	0.637	7.68	10.31	4.71	18.24
1985	6513.6	0.140	0.632	7.65	9.99	4.90	18.18
1986	6706.3	0.136	0.627	7.61	9.36	5.29	17.70
1987	7141.6	0.133	0.627	7.60	8.90	5.59	17.40
1988	7346.4	0.129	0.633	7.59	8.53	5.91	17.17
1989	7403.8	0.125	0.642	7.50	8.41	6.23	17.11
1990	7410.1	0.122	0.653	7.43	8.18	6.40	16.92
1991	7595.4	0.120	0.658	7.40	7.75	6.49	16.87

Notes: This table shows author's calculations from register data generated by Statistics Norway. Expenditure values in 2011 PPP dollars. Teaching Hours Per Pupil Proxy defined as sum of contracted hours for employees in Primary and Lower-Secondary Schools.

The table shows that municipal per-pupil spending on education almost doubled from 1981 to 1991, while the share of students in primary and lower-secondary school dropped from around 15% of the total population to 12% in 1991. Although the number of students per teacher and class size decreased, along with an increase in the teaching hours proxy[6], the average number of public schools declined after 1983.

Table 3 additionally shows descriptive statistics by cohort group, with all variables fixed at ages between 33 and 35. Similar to the trends shown above, average schooling increased by over one year of study for Norwegian residents born between 1964 and 1967 compared to those born between 1980 and 1983, with a similar pattern observed in parents' educational levels. Yearly earnings, on the other hand, nearly doubled between those cohorts.

[5]Oslo, Bergen, Trondheim, and Stavanger

[6]Contracted hours from employed workers in primary and lower-secondary schools

Table 3: Individual-Level Sample Averages

Cohort Group (year of birth)	1964-67	1968-70	1971-1975	1976-79	1980-83
Number of Observations	262,506	199,475	307,030	207,059	200,986
Years of Study (at age 33-35)	12.8	13.2	13.6	13.9	14.0
Yearly Earnings (at age 33-35)	22,463.5	25,793.8	31,477.7	37,744.6	41,431.1
Man (Share)	51.4 %	51.3 %	51.0 %	51.1 %	51.3 %
Mothers' Years of Study	11.1	11.3	11.6	11.9	12.2
Fathers' Years of Study	11.7	11.9	12.2	12.5	12.6
Nordic Foreigners	0.9 %	0.7 %	0.6 %	0.4 %	0.2 %
Other Foreigners	2.3 %	2.2 %	2.3 %	2.0 %	1.5 %

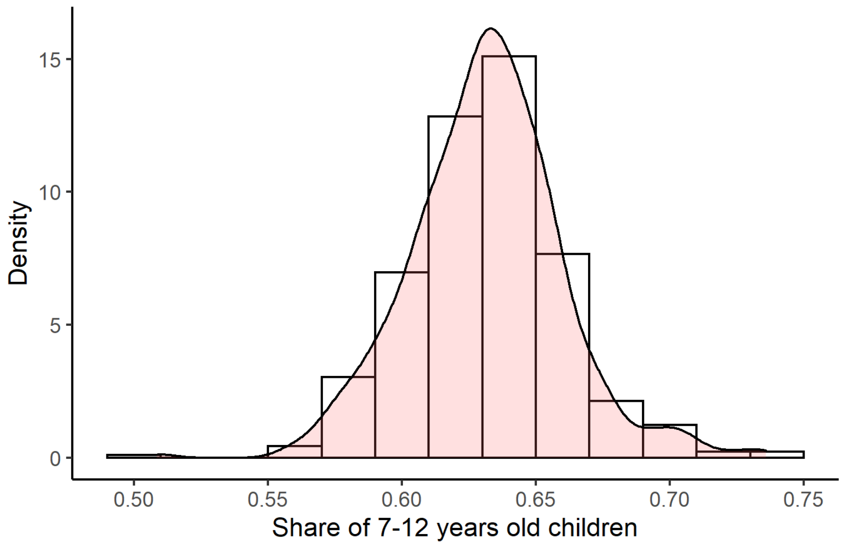
Notes: This table shows author's calculations from register data generated by Statistics Norway. Sample is restricted to students who were born between 1964 and 1983 and were living in a Norwegian Municipality in the year of 1985. Annual earnings are measured in dollars, adjusted for 2011 purchasing power parity (PPP), excluding 1st and 99th percentiles.

3.2 Empirical Procedure

3.2.1 Estimating Shock Size

I leverage cross-municipality variation in the pre-reform share of children aged 7 to 12 over the total of children and teenagers aged 7 to 15. Figure 1 shows the share of 7-12-year-old children among those of primary and lower-secondary school age, which will be the treatment intensity variable, by municipality in 1985. The distribution shows no clear regional patterns. Most municipalities had a share between 55% and 70%, indicating a relatively small range for the treatment variable, with a standard deviation of about 0.029. However, a few municipalities exhibit more extreme shares, around either 50% or 75%.

Figure 1: Density of the share of children aged between 7 and 12 years old in 1985



Notes: This figure shows author's calculations from register data generated by Statistics Norway and tabulated by Kommunedatabasen. The share is relative to population aged between 7 and 15 years old.

Estimating the shock size from the 1986 reform in Norway's educational grant system is achieved through a detailed formula that captures changes related to student demographics. This transition is quantified by comparing pre- and post-reform scenarios, reflecting shifts in funding allocations across different educational levels—primary and lower-secondary. The formula is given by:

$$\begin{aligned} Shock_m &= SW \times \hat{CF} \times [(H_p \times sh712_m) + (H_s \times (1 - sh712_m))] \\ &- [(SW \times H_p \times CF_{\text{primary}} \times sh712_m) + (SW \times H_s \times CF_{\text{secondary}} \times (1 - sh712_m))], \end{aligned} \tag{1}$$

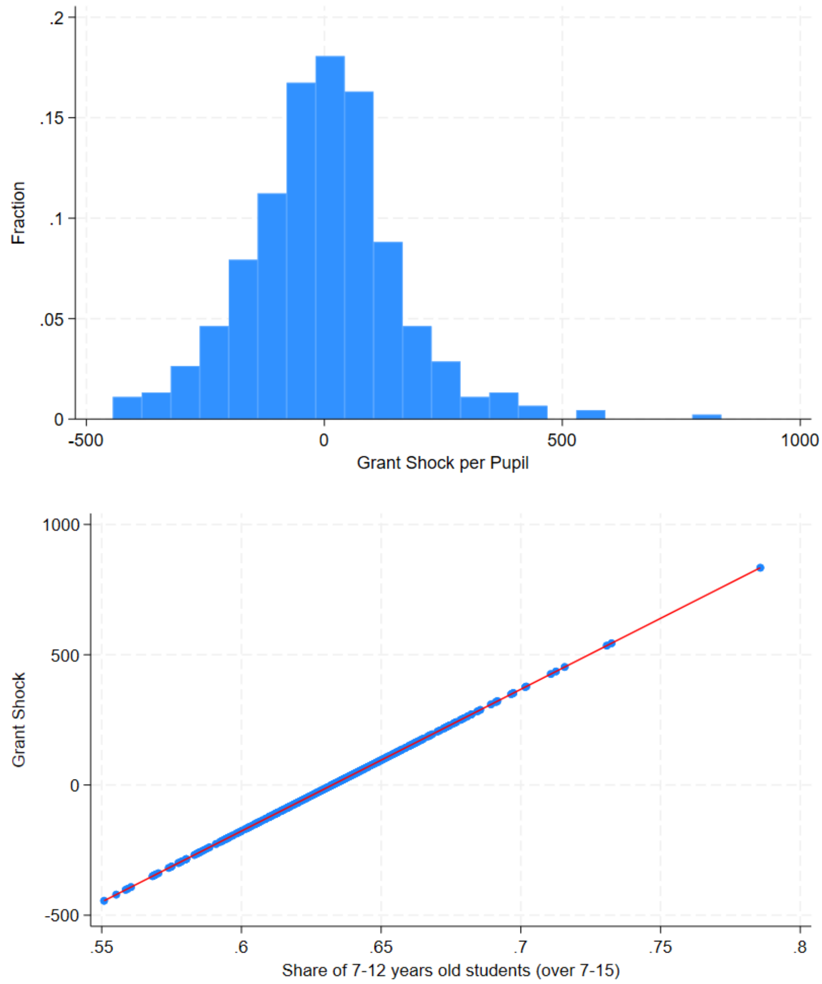
where SW is the number of school weeks per year, reflecting the annual duration of educational activities; H_p and H_s denote the weekly teaching hours for primary and lower-secondary education, respectively; CF_{primary} and $CF_{\text{secondary}}$ represent the pre-reform cost factors for each educational level, illustrating the financial parameters set by the central administration before the reform; $sh712_m$ denotes the share of students aged 7-12 in the total population of students aged 7-15 in a municipality m in 1985; and $\hat{CF}$ is the simulated unified cost factor post-reform, designed to balance the aggregate grant in the year prior to the reform.

For practical application, the parameters are set as follows: the school year comprises 39 weeks; primary education involves 25.2 teaching hours per week, the maximum allowed for funding, while lower-secondary education involves 47.5 teaching hours per week. The pre-reform cost factors were \$30.2 for primary and \$34.1 for lower-secondary education, based on 1985 values. Post-reform, a unified cost factor of $32 was established to maintain the overall average spending per student across the nation. The resultant equation, incorporating these specific values, precisely quantifies the shock as the differential in grant funding attributable to the reform's implementation.

The introduction of the unified cost factor at $32 was strategically chosen to ensure that the total national grant change would be zero, assuming no significant increase or decrease in overall spending. The calculated shock size reflects the redistribution of educational grants under the new rules, highlighting the differential impact on municipalities depending on their demographic composition, specifically the age distribution of their student populations.

Figure 2 shows the distribution of the estimated education transfer amounts to municipalities. All values are estimated in terms of 2011 PPP dollars per pupil.

Figure 2: Distribution of Shock Size Estimates



Notes: This table shows author's calculations from register data generated by Statistics Norway. Expenditure values in 2011 PPP dollars. Grant shock is defined by formula 1.

The histogram displays the distribution of grant shocks per pupil, ranging mostly from -$500 to $500, with a standard deviation of $137. The distribution is slightly right-skewed, with a few outliers receiving substantial increases. The scatter plot illustrates a positive correlation between the share of 7-12-year-old students (out of the total of 7-15-year-olds) and the grant shock received by municipalities. The data points show a clear linear relationship: as the proportion of younger students increases, so does the grant shock.

Given the range of the shock across municipalities, all estimates will be presented in terms of an additional yearly $100 per pupil (in 2011 PPP dollars), which represents around 1.5% of the total expenditure in 1985. However, it is important to underscore that such a procedure assumes a linear relationship between the grant shock and its impacts, which may not fully capture the actual dynamics observed in the data.

3.2.2 Municipal-level Analysis

At the municipality level, I estimate models of the following form:

$$Y_{m,t} = \sum_{q=-1985} \pi_q(1[q = t]Shock_m) + \phi X_m' + \gamma_m + \delta_t + \vartheta_{ct,t} + \epsilon_{m,t}, \quad (2)$$

where γ_m, δ_t, and $\vartheta_{ct,t}$ are municipal, year, and county-by-year fixed effects, which control for any changes within the same region. X_m is a matrix of demographic controls for all criteria that may influence education spending. Since rural and central municipalities have significantly different contexts that might not be perfectly captured by covariates, there will also be fixed effects for dummies identifying the level of centrality[7] interacted with year. Additionally, I use the 1982-85 average Share of Tax Revenue (as a proportion of all revenues) and the 1981-85 average Share of Education Expenditure (as a proportion of all expenditures), which were part of the criteria for pre-reform grant distribution, both interacted with each year. Since there is concern that the new rules might also affect other sources of central administration funding, controls for Health Sector Matrix Points will also be included. These refer to a formula introduced during the 1986 intergovernmental transfers reform, used to allocate grants for health services. This variable is constructed using both the Health Sector grant weights and pre-1986 municipal characteristics based on demographics. Finally, I add controls related to municipalities' demographics, namely: the share of children aged 7 to 15, and adults from age 21 to 64, over the total population. The overal size of the population, in log points, is also included.

By non-parametrically tracing out the full adjustment path of the treatment

[7] Centrality refers to a municipality's geographical location in relation to towns of different sizes, with 7 levels. It was measured in 1980 by the Norwegian Statistics Bureau.

effect via equation (1), I can examine the reform's gradual implementation. As discussed in subsection 2.3, the variation in the underlying criteria does not lead to an immediate treatment impact. Pooling three three-years periods, I also provide a differences-in-differences analysis with phase-in and full treatment periods, for which I use the following specification:

$$Y_{m,t} = \beta_1(1[t \in 1986{-}88]Shock_m)+\beta_2(1[t \in 1989{-}91]Shock_m)+\phi X_m^{'}+\gamma_m+\delta_t+\vartheta_{ct,t}+\epsilon_{m,t} \tag{3}$$

where β_1 and β_2 express the level changes in the grouped years of 1986-88 and 1989-91, respectively. Both will measure the difference to the baseline years of 1983-85.

The main assumption underlying the identification approach is similar to that in all differences-in-differences analyses: that all trends across municipalities, controlling for introduced covariates and fixed effects, would have remained unchanged in relation to the share of 7-12-year-old children (out of 7-15-year-olds) after the reform, had it not occurred. Therefore, this relative time parameter should be flat and not statistically significantly different from zero in the pre-reform period, which will be tested. In addition to the parallel trend assumption, the validity of the results requires that the reform does not coincide with any shocks or policies that might influence post-reform outcomes.

3.2.3 Individual-level analysis

I develop a similar design for individual outcomes, replacing year fixed effects with cohort fixed effects (c). I use cohort groups (g) interacted with the expected shock to estimate the effects in a flexible way. Table 4 shows the cohorts' ages by year, grouped into five categories: those who were never exposed to the reform changes and were born between 1964 and 1967, those who were also not exposed and were born between 1968 and 1970 (serving as the baseline in the regressions), those who were marginally exposed and were born between 1971 and 1975, those who were fully exposed in lower-secondary education and were born between 1976 and 1979, and finally, those who were fully exposed in primary education and were born between 1980 and 1983.

Table 4: Cohort age by year

Cohort	Group	1986	1987	1988	1989	1990	1991
1964	Older Cohorts	22	23	24	25	26	27
1965		21	22	23	24	25	26
1966		20	21	22	23	24	23
1967		19	20	21	22	23	24
1968	Not exposed	18	19	20	21	22	23
1969		17	18	19	20	21	22
1970	[Baseline in Regressions]	16	17	18	19	20	21
1971	Marginally exposed	15	16	17	18	19	20
1972		14	15	16	17	18	19
1973		13	14	15	16	17	18
1974		12	13	14	15	16	17
1975		11	12	13	14	15	16
1976	Exposed at Lower Secondary School	10	11	12	13	14	15
1977		9	10	11	12	13	14
1978		8	9	10	11	12	13
1979	Exposed at Primary School	7	8	9	10	11	12
1980		6	7	8	9	10	11
1981		5	6	7	8	9	10
1982		4	5	6	7	8	9
1983		3	4	5	6	7	8

Notes: This table shows how cohorts will be grouped in the individual level regressions. Children that were above 15 by the year of 1986 were already out of compulsory school. Children grouped into 'Never exposed' will be used to test for pre-trends.

The individual-level effects are estimated using equation 4 below.

$$Y_{i,g} = \sum_{q=-1}^{3} \pi_q(1[q = g]Shock_m) + \phi X'_{m,1985} + \alpha U'_i + \gamma_m + \delta_c + \vartheta_{ct,c} + \epsilon_{i,c} \qquad (4)$$

In addition to the municipal controls and fixed effects discussed earlier, the individual-level analysis will also include gender and foreigner[8] dummies, as well as the educational levels of the individual's mother and father and within-family birth order, since Black et al. [2011] find a strong and significant effect of birth order on IQ. Since Table 3 shows clear trends in parental educational level and the share of foreigners across cohorts, these controls will be interacted with the year of birth. Finally, to pick up any cofounding effects with the local labor market characteristics, I also interact year of birth with labor market regions, classified by Statistics Norway, based on information about commuting flows and analogous to European Statistical Office NUTS4 level.

The variable $Shock_m$ will be assigned based on the municipality where the indi-

[8]Foreigners are categorized into Nordic (born in Sweden, Denmark, Finland, or Iceland) and others.

vidual lived in 1985, one year prior to the reform. This means the coefficients will be intention-to-treat estimates, as not all students lived in the same municipality in subsequent years. This choice addresses the potential threat of bias, as null treatment coefficients could reflect sorting-into-treatment, especially if more concerned parents moved based on where education spending or quality was increasing [Nechyba, 2006; Caetano, 2019]. This hypothesis is tested in the appendix.

Other parental responses to the shock may also occur in terms of their own efforts to enhance their children's human capital accumulation. However, the evidence on the magnitude and direction of this response is mixed. While Houtenville and Conway [2008] provides suggestive evidence of a reduction in parental effort relative to school inputs, Datar and Mason [2008] finds very small effects (3-7% of a standard deviation) with no impact on students' achievement. Finally, Bonesrønning [2004] found no strong evidence of parental responses to different class sizes, although there is some indication that parents reduce their efforts as class sizes increase (a complementary response). The Norwegian context of heavily publicly funded education and low income inequality suggests a potentially low magnitude and impact of parental responses on the effort margin.

I also provide a linear approach to the analysis by interacting the school funding shock, calibrated for each cohort's specific exposure, with continuous variables representing the (potential) years of exposure. Instead of simply pooling the more and less exposed cohorts, I examine how the effects of the shock vary depending on the length of time the cohort was exposed to it. The parameter estimation will be expressed in terms of the full 9 years of exposure, providing a basis for comparison across the entire implementation period.

$$Y_{i,c} = \pi Shock_{m,c} \cdot \text{Years of Exposure}_{i,c} + \phi X^{'}_{m,1985} + \alpha U^{'}_{i} + \gamma_m + \delta_c + \vartheta_{ct,c} + \epsilon_{i,c}, \quad (5)$$

where Years of Exposurei, c is the number of years for which students were school-aged after 1986, which varies from 0 to 9; $Shock_{m,c}$ is a cohort- and municipality-specific adjustment of the original shock variable ($Shock_m$), calculated to account for the phased implementation of the policy, adjusting the magnitude of the shock depending on the year of birth and capturing the gradual increase in the policy's impact. π represents the coefficients of interest.

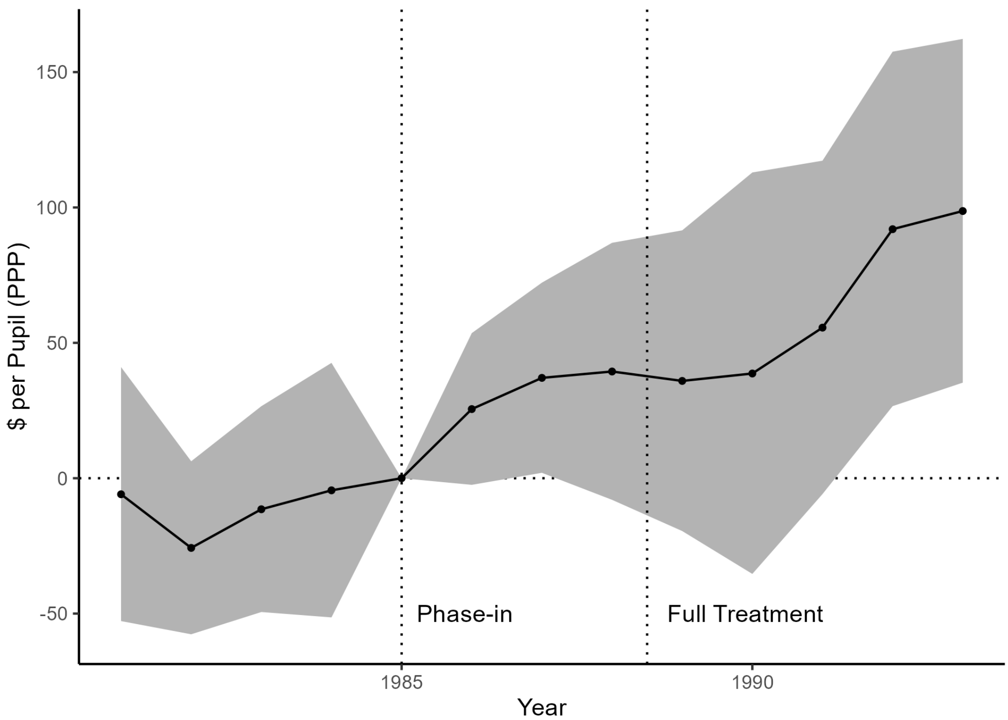
This model imposes a linear structure by interacting the calibrated school funding shock with a continuous variable representing the length of exposure. This approach allows the analysis to examine how the average effect size of the shock varies by each year of exposure. However, a limitation of this model is that it does not test for pre-existing trends or non-linear effects. Despite these limitations, the linear specification approach offers a valuable comparison with existing literature, allowing for an assessment of how the effects of increased school funding in this case relate to previous findings.

4 Results

4.1 Municipal-level Results

Graph 3 shows the municipal response on gross operational expenditures per pupil, year by year, to an increase of $100 in intergovernmental transfers to education. Operational expenditures includes staff compensation and day-to-day supplies, such as teaching materials.

Figure 3: Effect of $ 100 higher grant on Education Gross Operational Expenditures

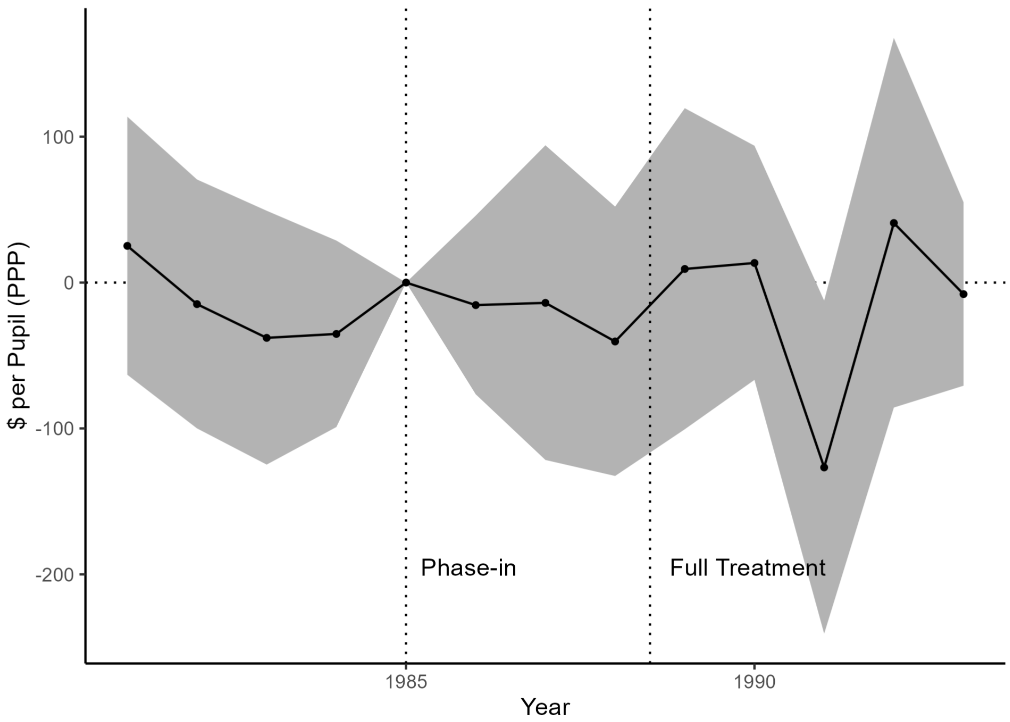


Notes: This figure shows the results from estimating Equation 2. Dots represent the π_q estimates; gray area represent 90% confidence intervals, clustered at the municipality level. Sample is 402 Norwegian municipalities in 1985 that had the same borders throughout the period.

Figure show that coefficients are mostly flat prior to the baseline year, but they increase starting in 1986, being significantly positive in the early 1990s. This result is expected due to the gradual implementation of the reform, as discussed in subsection 2.3. It is worth noting that the effect of an additional $100 per pupil on the grants corresponds, at the later period, to around $100 on expenditures. The magnitude shows the consistency between the shock size and the spending response.

Figure 4 shows the effect of additional funding on capital and maintenance expenditures. It shows that effect of additional funding is null. Thus, the shock is channeled mostly to payroll, with no response, negative or positive, on other types of expenditures.

Figure 4: Effect of $ 100 higher grant on Education Gross Capital and Maintenance Expenditures



Notes: This figure shows the results from estimating Equation 2. Dots represent the π_q estimates; gray area represent 90% confidence intervals, clustered at the municipality level. Sample is 402 Norwegian municipalities in 1985 that had the same borders throughout the period.

Table 5 shows results on school inputs, with the data segmented into two periods: Phase-in (1986-88) for initial effects and Full Treatment (1989-1991) for sustained effects. There is evidence that municipalities used the additional resources to hire more teachers. Interestingly, class size remained unchanged, indicating that the additional teaching hours were likely used for more tutoring or extracurricular activities.

Table 5: Municipal-level regressions

Outcomes	(1) Teachers (log)	(2) Teachers per Pupil	(3) Class Size	(4) Teachers' Education	(5) Teachers' Income (ln)	(6) Number of Schools
Phase-in	0.007**	0.001	-0.0001	0.001	0.018	0.022
(1986-88)	(0.003)	(0.001)	(0.017)	(0.004)	(0.044)	(0.018)
Full Treatment	0.011***	0.002***	0.011	-0.004	-0.041	0.048
(1989-91)	(0.004)	(0.001)	(0.024)	(0.006)	(0.060)	(0.033)
Pre-Treat. Mean		0.107	17.7	14.2		7.6
Number of Mun.	378	402	402	378	378	402
Pre-trend p-value	0.259	0.199	0.018	0.373	0.794	0.132

Notes: This table shows author's estimations from register data generated by Statistics Norway. Calculations are estimates from Equation 3. Standard errors clustered by municipality in parentheses. Sample is 402 Norwegian municipalities that had the same borders throughout the period, from 1983 to 1991. Column (1) has 24 municipalities with missing data. *** p<0.01, ** p<0.05, * p<0.1

These results indicate that municipalities primarily used the additional funds to hire teachers. Excluding the four largest cities in Norway, the results remain significant for the hiring of teachers, but not for the number of schools, as shown in Table 12 in the appendix.

4.2 Individual-level Results

After examining the effects of increased educational spending and how these funds were allocated, we now turn to the direct outcomes of this financial shift on the students themselves. Specifically, we investigate whether the additional funding influenced and labor market performance for those who experienced these changes during their schooling years. Table 6 presents the results of our regression analyses, employing both a flexible approach and a linear specification approach based on equations 4 and 5, respectively. We report earnings in two formats: absolute yearly labor income (in 2011 PPP dollars) and labor income rank by cohort (year of birth). Additionally, Graph 9 in the appendix visually details the earnings effects segmented by year of birth, rather than cohort groups. This analysis provides a comprehensive understanding of how increased educational investments have translated into tangible educational and economic outcomes for affected individuals.

Table 6: Individual-level regressions

VARIABLES	(1) Employment Status	(2) Annual Earnings	(3) Income Rank by Cohort
Flexible Approach			
Older Cohorts	0.001	70.20	0.001
	(0.001)	(63.38)	(0.001)
Marginally Exposed	0.002**	115.1*	0.002**
	(0.001)	(62.77)	(0.001)
Exposed at Lower-Secondary School	0.002*	99.01	0.002
	(0.001)	(82.78)	(0.001)
Exposed at Primary School	0.002*	312.6***	0.005***
	(0.001)	(88.89)	(0.001)
Linear Specification Approach			
9 Years of Exposure	0.002	249.0***	0.004***
	(0.001)	(81.56)	(0.001)
Pre-treatment Mean	0.930	31381	.5
Observations	1,024,535	981,306	994,205

Notes: This table shows author's estimations from register data generated by Statistics Norway. Calculations are estimates from Equation 4 and 5. Standard errors in parentheses are clustered by municipality the students were living in 1985. Sample is restricted to individuals born between 1964 and 1983 who resided in Norwegian municipalities in 1985, which had not changed borders. Annual earnings are measured in dollars, adjusted for 2011 purchasing power parity (PPP), excluding 1st and 99th percentiles. *** p<0.01, ** p<0.05, * p<0.1

The interpretation of the flexible approach is that $100 of additional education resources during primary education led to an increase on annual earnings of $312.6 around the age of 33 to 35, which is also reflected in a higher cohort labor income rank. For those exposed to the same shock during lower-secondary school, the estimate is considerably smaller and less significant, while those marginally exposed to the shock show no significant effect. The linear specification approach reveals a consistent pattern of effects across both earnings. On average, nine years of exposure to an additional $100 per pupil results in an increase of $249 in annual earnings.

The results from the linear specification approach are consistent, as expected, with those from the flexible approach. It is worth noting that in terms of magnitude, the increase in earnings represents little less than 1% of the pre-treatment mean—similar to the relative size of the shock, as described in subsection 3.2.1 and shown in Figure 3.

Building on the investigation on the long term effects, it is important to understand the underlying processes driving the increase in earnings. I analyze the influence of school funding on education outcomes, examining how these factors contribute to the economic outcomes observed.

Table 7 displays regression results for educational attainment, the probability of holding a degree in STEM (in addition to Law, Business & Medicine), cognitive abilities (in IQ scale) and expected earnings by education path. This analysis aims to determine the extent to which enhanced funding affects cognitive development and educational experiences, which are hypothesized to mediate the relationship between funding and earnings.

Table 7: Potential Educational Outcomes

VARIABLES	(1) Years of Study	(2) College Diploma	(3) STEM+	(4) Expected Wage	(5) Cognitive Abilities
Flexible Approach					
Older Cohorts	-0.004	-0.0001	0.0003	-26.89	-0.063
	(0.009)	(0.002)	(0.001)	(30.03)	(0.087)
Marginally Exposed	0.001	-0.0001	-0.0001	11.15	0.019
	(0.009)	(0.002)	(0.001)	(26.97)	(0.079)
Exposed at Lower-Secondary School	0.004	0.002	-0.002	-15.32	-0.062
	(0.011)	(0.002)	(0.001)	(32.77)	(0.094)
Exposed at Primary School	0.026**	0.004**	0.003**	86.82***	0.108
	(0.012)	(0.002)	(0.001)	(33.50)	(0.086)
Linear Specification Approach					
9 Years of Exposure	0.027***	0.005**	0.003***	93.83***	0.121*
	(0.010)	(0.002)	(0.001)	(29.47)	(0.065)
Pre-Treatment Mean	12.99	0.327	0.122	10,212.5	100.5
Observations	1,024,535	1,024,535	1,024,535	1,024,535	504,710

Notes: This table shows author's estimations from register data generated by Statistics Norway. Calculations are estimates from Equation 4 and 5. Standard errors in parentheses are clustered by municipality the students were living in 1985. Sample is restricted to individuals born between 1964 and 1983 who resided in a Norwegian municipalities in 1985, which had not changed borders. Annual earnings are measured in dollars, adjusted for 2011 purchasing power parity (PPP), excluding 1st and 99th percentiles. Expected wage is measured with a mincerian regression on level-specification attainment, as specified in section 3. Cognitive Abilities are measured in IQ scale, measured by the military draft for men, from ages 18 to 19. *** p<0.01, ** p<0.05, * p<0.1

According to the linear specification approach, students exposed to 9 years of additional $100 dollars school funding have higher 0.027 years of study by the age of 35, which corresponds to an increase in 0.005 of the likelihood of holding a college degree. They also have higher a likelihood of holding a college diploma in STEM or law, business or medicine. Their educational paths lead to an expected earnings increase of about $93 in their annual earnings. Their cognitive abilities also increase by 0.12 IQ points.

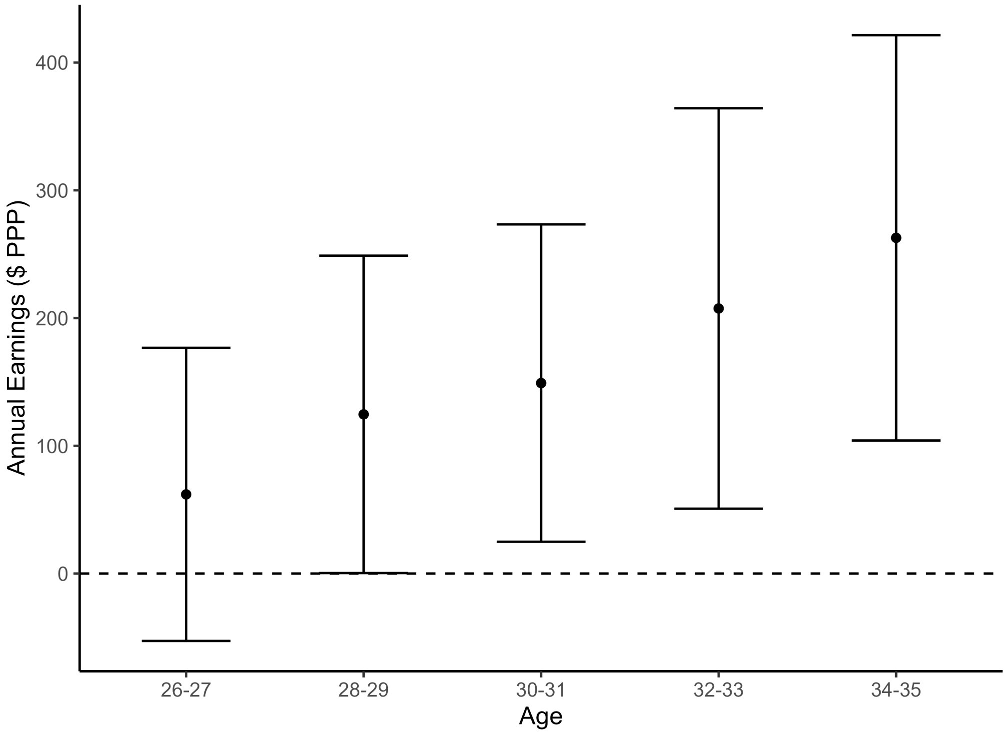
The literature, documented by Jackson and Mackevicius [2023], reports that a sustained increase of $1,000 in per-pupil school spending over four years typically results in a 0.0539 increase in the probability of obtaining a college degree, with most effects ranging between 0.05 and 0.5. My estimates indicate a proportionally lower effect. However, it is important to clarify that these are intention-to-treat estimates, as detailed in subsection 3.2.1. Additionally, a linear relationship between the funding increase and educational outcomes may not fully capture the observed data.

However, my results show that not only educational attainment increases, but students also are more likely to graduate in subjects that are better paid (STEM, law, business or medicine). Their educational paths lead to higher earnings that account to to about one third of their total increase in earnings showed in table 6.

In additional, my results also show some small effects on cognitive abilities. The effect size os consistent with the meta-analysis by Ritchie and Tucker-Drob [2018], which suggests that one additional year of study can raise cognitive abilities by as little as 1 to 5 IQ points per additional year. That is, if a linear relationship could be trusted, the funding shock leading to a full year of study would also lead to an increase of about 4 IQ points.

It is also important to understand how the effects on earnings evolve over time, drawing a path of school funding benefits throughout an individual's career. In order to elucidate the temporal dimension of these impacts, Figure 5 presents the estimated effects of higher exposure to the educational funding shock on earnings across various age groups, focusing on the linear specification approach.

Figure 5: Effect on Earnings by Age



Notes: This figure shows author's estimations from register data generated by Statistics Norway. Calculations are estimates from Equation 5. Standard errors are clustered by municipality the students were living in 1985. Sample is restricted to individuals born between 1964 and 1983 who resided in Norwegian municipalities in 1985, which had not changed borders. Annual earnings are measured in dollars, adjusted for 2011 purchasing power parity (PPP), excluding 1st and 99th percentiles.

Figure shows that the effects increase with age, suggesting cumulative benefits over time. For the youngest age group, the impact of additional $100 on school funding over nine years is positive but not statistically significant. The effect becomes statistically significant and larger at older ages. The magnitude of the effect peaks by the ages of 34-35. This highlights the importance of early educational investment for long-term earnings potential.

Those results connect the micro-level outcomes of increased funding to the full economic impact. In summary, they illustrate how educational and cognitive channels of influence long-term income benefits.

4.3 Impact across earnings distribution and parental education

To comprehensively understand the effects of educational funding, it is crucial to explore not just the average impacts but also how these effects are distributed across different segments of the population. This, I can shed light on the policy's potential to address inequalities and social mobility. First, Norway's extensive population-wide registers allow me to employ quantile regressions, providing new insights into the distributional impacts of increased school funding.

Quantile regression analysis, as outlined by Machado and Silva [2019], allows me to examine the effects of the funding increase across various points of the labor income distribution. Focusing on the linear specification approach, Table 8 shows results by five quantile points, ranging from 0.1 to 0.9.

Table 8: Quantile regressions on annual earnings

	(1)	(2)	(3)	(4)	(5)
Quantiles	0.1	0.25	0.5	0.75	0.9
Linear Specification Approach					
9 Years of Exposure	355.7**	290.6***	246.1***	205.8**	161.3
	(157.1)	(91.50)	(72.33)	(89.36)	(131.2)
Pre-Treatment Quantile	5,350.1	19,107.2	31,317.0	41,068.3	53,480.2
Relative effect	0.066	0.015	0.008	0.005	0.003
Observations	981,306	981,306	981,306	981,306	981,306

Notes: This table shows author's estimations from register data generated by Statistics Norway. Calculations are estimates from Equation 5. Standard errors in parentheses are clustered by municipality the students were living in 1985. Sample is restricted to individuals born between 1964 and 1983 who resided in Norwegian municipalities in 1985, which had not changed borders. Earnings outliers excluded. Annual earnings are measured in dollars, adjusted for 2011 purchasing power parity (PPP), excluding 1st and 99th percentiles. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

The results show a positive and significant impact of the shock at lower quantiles, which diminishes and becomes non-significant at the 90th percent of the distribution. Such findings indicate that additional educational funding predominantly benefits those at the lower-end of the earnings distribution, potentially reducing income disparities. The highest point estimate is found at the 0.1 quantile, showing an increase of about $350 in earnings, which corresponds to an increase of 6.6% of the baseline. Altogether, the patterns indicate that increasing school funding has an equality-enhancing effect on earnings decades later, suggesting a larger impact for low-skilled workers.

To further investigate this hypothesis, it is important to understand whether the effects of additional resources for education observed in the previous sections were experienced across students from different backgrounds. Recent literature has identified a more prominent role of school investments for low-SES students [Dearden et al., 2002; Heinesen and Graversen, 2005; Belmonte et al., 2020].

To address this, the student sample was divided based on parental education levels: one subgroup consists of students whose parents do not hold an upper-secondary education degree, and another where at least one parent does. The results, shown in Table 9, indicate that the benefits of increased funding are predominantly observed among students from lower-SES backgrounds.

Table 9: Results by Parental Education

	(1)	(2)	(3)
Linear Specification Approach			
Parental Education	Compulsory	Upper Secondary	Tertiary
9 Years of Exposure	343.1*	308.2***	45.65
	(192.8)	(97.07)	(147.2)
Pre-Treatment Mean	26997.4	31075.5	36331.0
Relative effect	0.013	0.010	0.001
Observations	161,766	519,433	300,107

Notes: This table shows author's estimations from register data generated by Statistics Norway. Calculations are estimates from Equation 5. Standard errors in parentheses are clustered by municipality the students were living in 1985. Sample is restricted to individuals born between 1964 and 1983 who resided in a Norwegian municipalities in 1985, which had not changed borders. Earnings outliers excluded. Annual earnings are measured in dollars, adjusted for 2011 purchasing power parity (PPP), excluding 1st and 99th percentiles. Groups defined by parental maximum educational attainment. *** p<0.01, ** p<0.05, * p<0.1

Results show that students with lower-educated parents drive the results. Only students with parents holding a college diploma show no significant effect, while the higher coefficient is found for students with parents holding only compulsory school diploma - both in absolute terms or relatively to the baseline.

5 Cost-benefit analysis

5.1 Internal Rate of Return

This section conducts a cost-benefit analysis to assess the aggregate economic impact of increasing educational funding by \$100 per pupil annually from grades 1 to 9. The purpose of this analysis is to determine the Internal Rate of Return (IRR), which indicates the efficiency of this policy in terms of the additional earnings it generates relative to its costs. This evaluation is crucial for policymakers, as it provides a quantitative measure of the long-term value of educational investments, helping to inform decisions on future educational funding.

To evaluate this policy, the cost of the additional funding is calculated as follows:

$$Cost = \sum_{t=7}^{15} \frac{100}{(1+r)^{t-6}} + \sum_{t=16}^{22} \frac{\mathbb{E}(\Delta Educ)}{(1+r)^{t-6}}, \tag{6}$$

where t ranges from the ages of 7 to 22, capturing the period from primary to tertiary education. The term $\mathbb{E}(\Delta Educ)$ represents the expected increase in the probability of obtaining a higher education degree multiplied by the average expenditure per pupil at these levels, sourced from the World Bank database[9]. The parameter r is the discount rate used to calculate the present value of future costs.

The benefits of the policy, defined as the present value of increased future earnings ($Benefit$), are calculated using:

$$Benefit = \sum_{t=28}^{60} \frac{\Delta Y}{(1+r)^{t-6}}, \tag{7}$$

where ΔY denotes the annual increase in earnings attributed to the policy, applied from the age of 28 to 60.

The policy's cost-effectiveness is determined by comparing the present value of benefits (PV) to the calculated costs (C). The Internal Rate of Return (IRR) is the discount rate r_{max} that equates the net present value of the investment to zero:

$$\sum_{t=28}^{60} \frac{\Delta Y}{(1+r_{max})^{t-6}} \geqslant \sum_{t=7}^{15} \frac{100}{(1+r_{max})^{t-6}} + \sum_{t=16}^{22} \frac{\mathbb{E}(\Delta Educ)}{(1+r_{max})^{t-6}} \tag{8}$$

This equation balances the discounted values of future earnings against the upfront costs, identifying the break-even point for the investment. Research such as Haider and Solon [2006] and Böhlmark and Lindquist [2006] supports the use of middle-aged earnings (ages 33-35) to estimate IRR due to the strong correlation with lifetime earnings during this period.

Based on these calculations, and as detailed in Table 6, the policy yields an IRR of 6.2% for the general population, increasing to 8% for students with low-educated parents. This enhanced rate for disadvantaged groups underscores the policy's role in reducing educational inequities.

5.2 Marginal Value of Public Funds

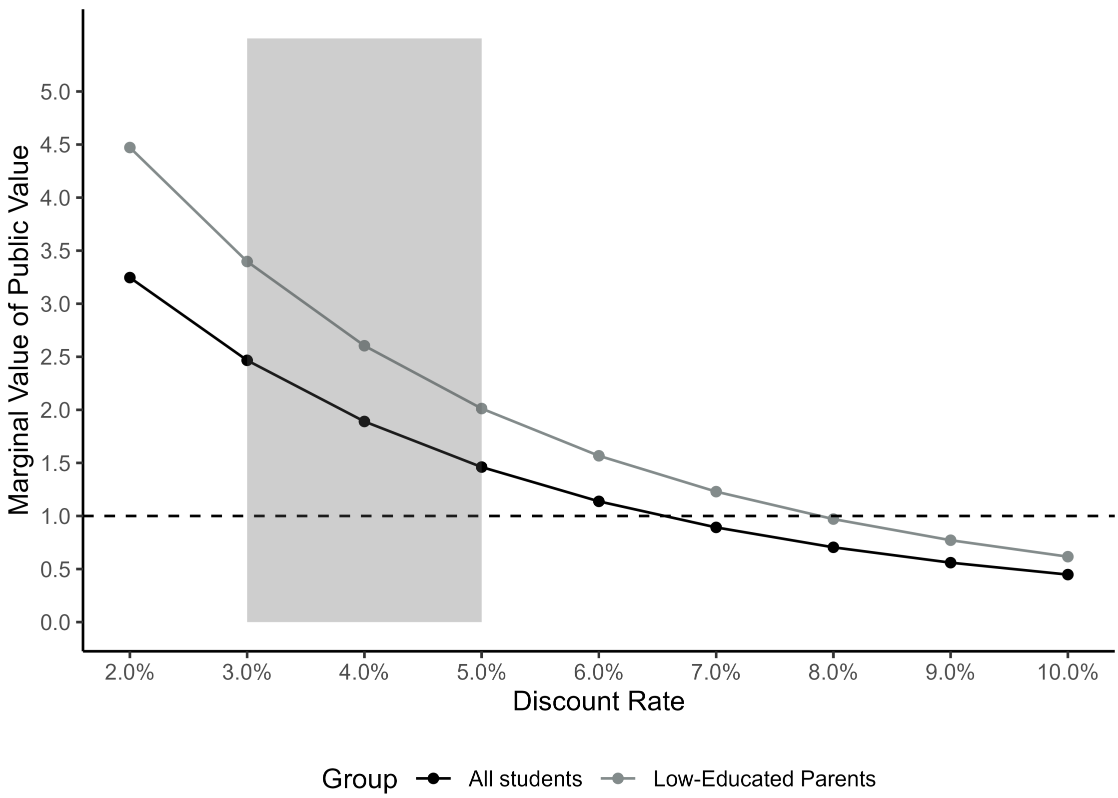
The MVPF is another benefit-cost framework, which produces a common metric for the relative effectiveness of spending on different programs, assuming a certain discount rate. It compares the benefits that a policy provides to society (society's willingness to pay) to the net cost to the government of implementing it [Hendren

[9]The spending value is the first one available from the 1990s, which is $13,280 in secondary education and $33,698 in tertiary education. The increased probability, estimated in Equation 5, is 0.003, significant at the 99% level.

and Sprung-Keyser, 2020]. So, instead of estimating the IRR, I discount the policy costs of benefits using a 3–5% discount rate [Barr et al., 2022]. The formula for the MVPF divides the benefits, expressed in equation 7, by the costs, expressed in equation 6.

Figure 6 shows that the MVPF ranges from 1.5 to 2.5, which means that society receives between \$1.5 and \$2.5 in benefits for every \$1 in government costs. In other words, even considering only its individual labor market benefits, and under attenuated intention-to-treat estimates, the benefits of increasing school funding are considerably larger than the costs. Even more interestingly, however, is that, when considering only students with low-educated parents, MVPF increases to a range between 2 and 3.4, which means that the economics returns of school funding is at least double its costs when targeted to those students.

Figure 6: Marginal Value of Public Funds of Additional \$100 for School Funding by Discount Rate and Benefited Students



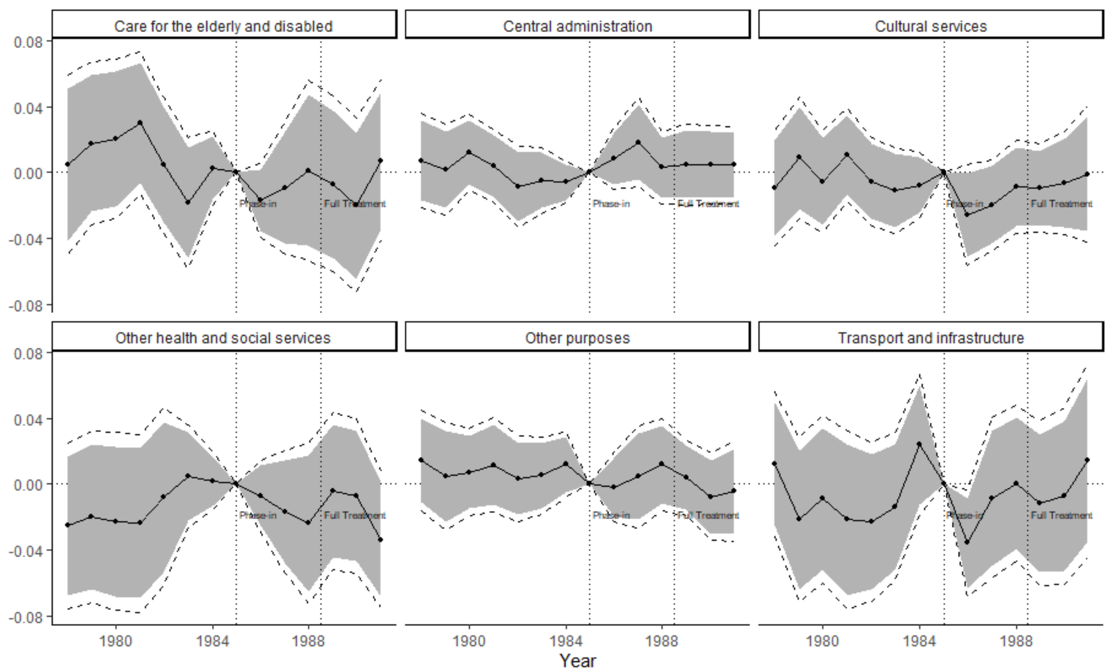
Notes: This figure shows author's estimations from register data generated by Statistics Norway. The MVPF is calculated dividing the benefits of additional \$100 in school funding, expressed in equation 7, by the sum of its total costs, expressed in equation 6, with estimates from equation 5. Sample is restricted to individuals born between 1964 and 1983 who resided in a Norwegian municipalities in 1985, which had not changed borders. Earnings outliers excluded. Low-educated parents are defined by no parent having educational attainment above compulsory school.

In conclusion, the analysis confirms the cost-effectiveness of the educational policy, particularly highlighting its significant returns for students from less advantaged backgrounds. These findings suggest that prior to the reform, there may have been underinvestment in education, especially for students from low-educated parents. For policymakers, this implies that further investments in education could yield substantial economic returns, contribute to more equitable educational outcomes, and strengthen the overall educational framework. This provides a compelling case for the continuation and expansion of similar funding policies.

6 Robustness Checks

In the municipal-level analysis, I find that municipalities with a higher share of primary school-aged children in 1985 experienced increased expenditure on education after that year. However, that shock might have correlated with increases in other sectors' spending, which could mean that the individual-level analysis results are influenced by other types of policies. Figure 7 shows the same regression as in Graph ??, applied to all other major sectors presented in the 'Strukturall for kommunenes økonomi' documents. The graphs show no impact of the shock on any other major sector. Therefore, central administration school funding was indeed channeled into education by municipalities.

Figure 7: Effect of $ 100 higher grant on big sectors' per capita expenditure (log)



Notes: This figure shows author's estimations from register data generated by Statistics Norway. Calculations are estimates from Equation 2. Dots represent the π_t estimates; bars represent 95% confidence intervals, clustered at the municipality level. Sample is 402 Norwegian municipalities in 1985 that had the same borders throughout the period.

One of the main concerns in the identification strategy relates to potential confounding variables associated with the demographics of the student population. The proportion of primary school-aged children (7-12 years) within the broader age group of primary and lower-secondary students (7-15 years) in each municipality serves as the main assignment variable in the analysis. However, this demographic characteristic may not be independent of other socio-economic or educational trends within the municipalities that could also influence children's outcomes over time.

To mitigate the risk of such confounding effects, I use a sensitivity analysis, narrowing down the age range used to define the demographics of interest. Focusing on a more specific age cohort may potentially minimize the variability in external influences not directly related to the reform but instead linked to broader age-related trends within the municipalities. This narrower demographic window could help approximate a more randomized exposure to the reform, ensuring that we estimate the true effect of the reform, independent of other concurrent developmental or policy shifts. Thus, this approach may strengthen the validity of the conclusions drawn about the reform's impact by reducing the potential overlap of unrelated socio-economic trends and educational strategies across different municipalities.

To further validate the results and ensure that they are indeed capturing the impact of the funding reform rather than reflecting underlying variables correlated with students' demographic composition, I implement the linear specification approach using three different demographic windows. The first is the current age range (7-12/7-15), which has already been discussed. Additionally, I test two narrower age brackets: a six-year range (10-12/10-15) and a four-year range (11-12/11-14). By examining the effects across these varied age groups, the analysis aims to check for consistency in the impact of the funding reform. If the results remain statistically significant across all these demographic windows, it would strengthen the argument that the observed effects are indeed due to changes in funding, and not confounded by other demographic or socio-economic trends.

Table 10: Municipal-level regressions: Different Age Brackets

Outcomes	(1) Teachers (ln)	(2) Teachers Per Pupil	(3) Teachers' Education	(4) Teachers' Income	(5) Class Size	(6) Number of Schools
			7-12 / 7-15			
Phase-in	0.308**	0.0171	-0.305	-0.0156	1.951	1.125
(1986-88)	(0.148)	(0.0254)	(0.947)	(0.204)	(2.360)	(1.008)
Full Treatment	0.490**	0.075***	0.218	-0.306	-1.371	2.358
(1989-91)	(0.207)	(0.029)	(1.478)	(0.320)	(3.059)	(1.780)
Observations	4,374	4,374	3,215	3,214	4,384	4,374
			10-12 / 10-15			
Phase-in	0.358**	0.034	0.113	0.0596	1.229	0.768
(1986-88)	(0.142)	(0.0255)	(0.847)	(0.185)	(2.047)	(0.874)
Full Treatment	0.384**	0.092***	0.889	-0.173	-1.489	1.698
(1989-91)	(0.165)	(0.026)	(1.350)	(0.296)	(2.564)	(1.526)
Observations	4,374	4,374	3,215	3,214	4,384	4,374
			11-12 / 11-14			
Phase-in	0.321**	0.049**	-0.457	0.163	0.627	0.497
(1986-88)	(0.128)	(0.025)	(0.767)	(0.203)	(1.950)	(0.701)
Full Treatment	0.281**	0.088***	0.601	-0.0470	-1.425	1.660
(1989-91)	(0.128)	(0.021)	(1.253)	(0.317)	(2.370)	(1.283)
Observations	4,374	4,374	3,215	3,214	4,384	4,374

Notes: This table shows author's estimations from register data generated by Statistics Norway. Calculations are estimates from Equation 3, using students' age composition instead of grant shock. Standard errors clustered by municipality in parentheses. Sample is 402 Norwegian municipalities that had the same borders throughout the period. Column (1) has 24 municipalities with missing data. *** p<0.01, ** p<0.05, * p<0.1

Table 11: Individual-level regressions: Different Age Brackets

Age brackets	(1) Years of Study	(2) College Diploma	(3) Employment Status	(4) Annual Earnings	(5) Income Rank by Cohort
7-12 / 7-15	0.132**	0.022**	0.008*	1,343***	0.023***
	(0.056)	(0.010)	(0.005)	(395.4)	(0.005)
Observations	1,023,285	1,024,535	1,024,535	981,306	994,205
10-12 / 10-15	0.152***	0.024***	0.002	1,214***	0.022***
	(0.049)	(0.009)	(0.004)	(370.2)	(0.005)
Observations	1,023,285	1,024,535	1,024,535	981,306	994,205
11-12 / 11-14	0.110**	0.016*	0.003	1,010***	0.020***
	(0.044)	(0.008)	(0.004)	(320.2)	(0.004)
Observations	1,023,285	1,024,535	1,024,535	981,306	994,205

Notes: This figure shows author's estimations from register data generated by Statistics Norway. Calculations are estimates from Equation 5, using students' age composition instead of grant shock. Standard errors in parentheses are clustered by municipality the students were living in 1985. Sample is restricted to individuals born between 1964 and 1983 who resided in a Norwegian municipalities in 1985, which had not changed borders. Annual earnings are measured in dollars, adjusted for 2011 purchasing power parity (PPP), excluding 1st and 99th percentiles. *** p<0.01, ** p<0.05, * p<0.1

The empirical analysis across different demographic windows reveals a consistently positive and statistically significant impact of the educational reform on number of teachers in municipalities and various individual outcomes, regardless of the age bracket considered. This pattern underscores the robustness of the reform's effects, as even when the demographic window is narrowed—from the broader group of 7-12 years down to more focused groups—the estimated impacts remain positive. This consistency in outcomes across age groups strengthens the argument that the observed benefits are indeed attributable to the educational reform rather than external demographic or socio-economic factors. The findings suggest that narrower age brackets, while showing a natural decline in the magnitude of effects due to their different base, still significantly benefit from the reform. This consistency across different groups provides compelling evidence that the reform has broadly facilitated improvements in educational and economic parameters, reinforcing the effectiveness of targeted educational investments.

7 Conclusion

This study provides a comprehensive analysis of the long-term impacts of increased education funding on student outcomes, leveraging a broad intergovernmental transfer reform in Norway in the mid-eighties. The research reveals that additional funding led to notable improvements in educational resources at the local level, such as higher teacher-to-pupil ratios and increased teaching hours. However, the effects on school staff income and class size were minimal, suggesting a strategic allocation toward enhancing instructional intensity.

At the individual level, I demonstrate a significant impact of increased funding on educational attainment and labor income, mediated by educational choices, and a small increase in cognitive abilities. Moreover, quantile regressions and results by parental education indicate that the positive impacts of increased funding are more pronounced and significant for individuals at the lower end of the income distribution and for children from low-educated parents, suggesting an equality-enhancing effect of the funding increase. These results contribute significantly to the existing literature on education policies and student outcomes, showing a significant heterogeneity of the spending effects.

The cost-benefit analysis presented earlier strengthens the case for increased educational funding, demonstrating a notable Internal Rate of Return (IRR) on investments in education. This analysis is particularly revealing as it quantifies the financial returns of educational investments over the long term, showing that the benefits in terms of increased labor income significantly outweigh the costs of additional funding at a discount rate of up to 6.2%. This supports the argument that not only do educational investments improve educational and social outcomes, but they are also economically viable and offer a substantial return on public investments, particularly for students with low-educated parents, for whom the IRR rises to 8%.

Understanding the implications of these findings is crucial for policymakers in education. This research advances the literature by providing empirical evidence that increased educational spending can lead to significant improvements in student outcomes, even in contexts with already high levels of educational expenditure. It challenges the prevailing assumptions that the impact of additional educational resources diminishes in high-expenditure settings, highlighting the role of strategic funding allocations, such as enhancing teacher-to-student ratios and instructional intensity. For policymakers, the findings advocate for targeted increases in educational funding, especially in areas that directly impact instructional quality and access for low-income families, thereby promoting greater educational equity.

It is worth mentioning that previous studies on educational interventions in Norway have generally suggested that school input policies, such as changes in classroom size or direct modifications to physical infrastructure, yield limited effectiveness in enhancing student outcomes. This contrasts sharply with findings from the United States, where school spending reforms have frequently demonstrated positive impacts on student achievement, particularly in underfunded districts. These divergent results have fueled debates on the efficacy of increased educational spending across different educational systems and economic contexts.

This paper bridges these two strands of literature by examining the effects of a significant funding shock in Norway, a country typically characterized by high baseline expenditure levels. The findings suggest that schools and municipalities may indeed be better equipped to allocate educational resources to optimize student outcomes than previously acknowledged. By showing positive results from the funding intervention in a high-spending context, this study provides compelling evidence that increased funding can effectively enhance educational outcomes, rather than merely improving school inputs.

Additionally, this study contributes to a better understanding of how educational funding impacts various demographic groups, which can guide more effective and equitable policy formulations. By demonstrating the specific benefits for students from lower socio-economic backgrounds, the research underscores the potential of education policy as a tool for reducing inequality, helping to reduce income disparities through improved educational opportunities. Moving forward, these results can inform reforms that not only increase funding but also ensure that such investments are channeled into the most impactful areas, thereby enhancing the overall quality of education and its contributions to economic development and social cohesion.

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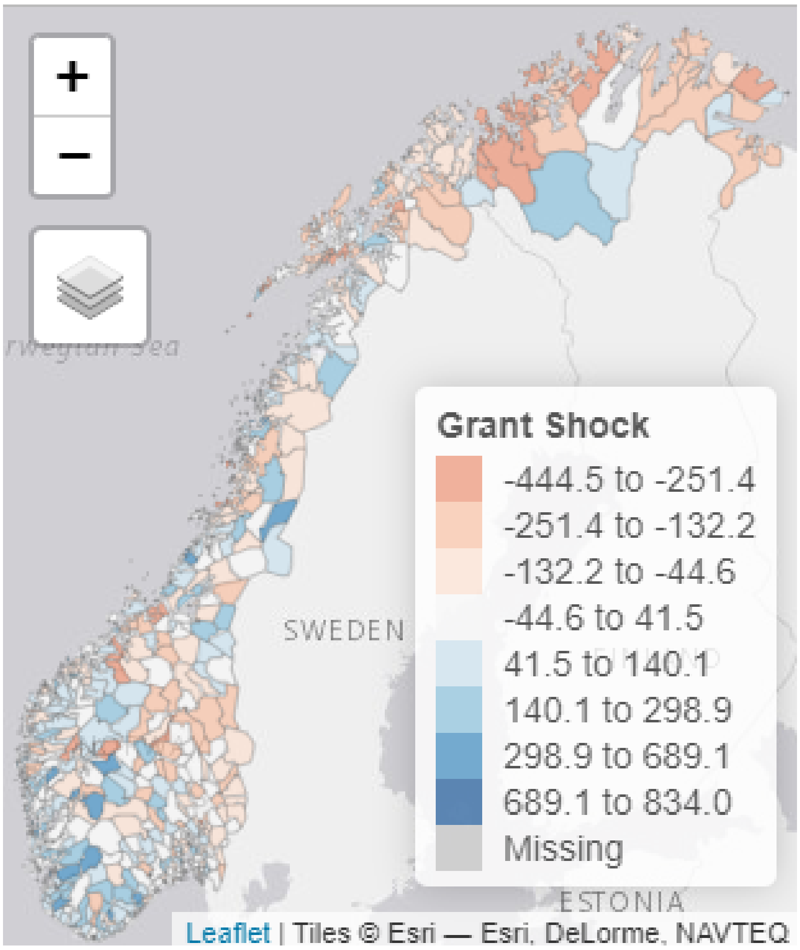
Appendices

Educational Level-Specialization Categories

1. Compulsory Education	
2. Upper Secondary School	First Year High School Diploma - Academic High School Diploma - Vocational
3. Vocational Tertiary Degree	Education Humanities and Arts Social Sciences, Business and Law Science, Mathematics and Computing Engineering, Manufacturing and Construction Agriculture and Veterinary Health and Welfare Services Unknown or General Programmes
4. College Degree	Education Humanities and Arts Social Sciences, Business and Law Science, Mathematics and Computing Engineering, Manufacturing and Construction Agriculture and Veterinary Health and Welfare Services Unknown or General Programmes
5. Master Degree	Education Humanities and Arts Social Sciences, Business and Law Science, Mathematics and Computing Engineering, Manufacturing and Construction Agriculture and Veterinary Health and Welfare Services Unknown or General Programmes
6. PhD Degree	Education Humanities and Arts Social Sciences, Business and Law Science, Mathematics and Computing Engineering, Manufacturing and Construction Agriculture and Veterinary Health and Welfare Services Unknown or General Programmes

Estimated Grant Shock

Figure 8: Estimated Grant Shock Geographical Distribution



Notes: This figure shows author's calculations from register data generated by Statistics Norway. Expenditure values in 2011 PPP dollars. Grant shock is defined by formula 1.

Municipal-level results

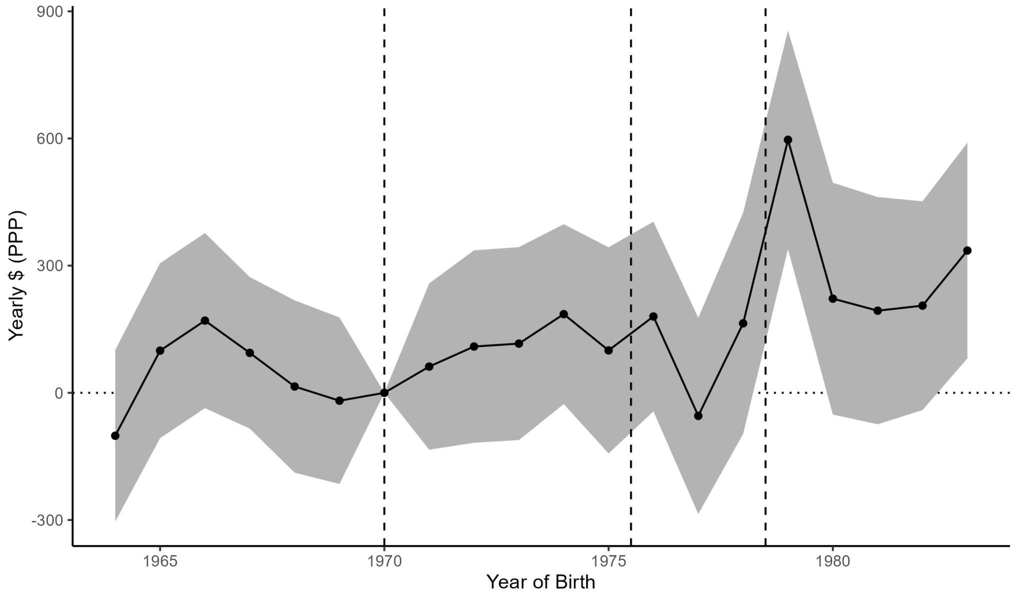
Table 12: Municipal-level regressions excluding big Cities

Outcomes	(1) Teachers (log)	(2) Teachers per Pupil	(3) Teachers' Education	(4) Teachers' Income	(5) Class Size	(6) Number of Schools
Phase-in	0.006**	0.0003	-0.005	-0.0003	0.045	0.020
(1986-88)	(0.003)	(0.0005)	(0.017)	(0.004)	(0.044)	(0.019)
Full Treatment	0.009**	0.0014***	0.005	-0.006	-0.012	0.039
(1989-91)	(0.004)	(0.0005)	(0.027)	(0.006)	(0.056)	(0.033)
Observations	4,330	4,330	3,179	3,178	4,734	4,726
Pre-Treat. Mean		0.105	14.2		18.2	7.3
Number of Mun.	398	398	374	374	398	398
Pre-trend p-value	0.613	0.252	0.457	0.803	0.040	0.337

Notes: This table shows author's estimations from register data generated by Statistics Norway. Calculations are estimates from Equation 3. Standard errors clustered by municipality in parentheses. Sample is 398 Norwegian municipalities that had the same borders throughout the period, excluding four biggest cities in Norway (Oslo, Bergen, Trodheim and Tromsø). Column (1) has 24 municipalities with missing data. *** p<0.01, ** p<0.05, * p<0.1

Individual-level results

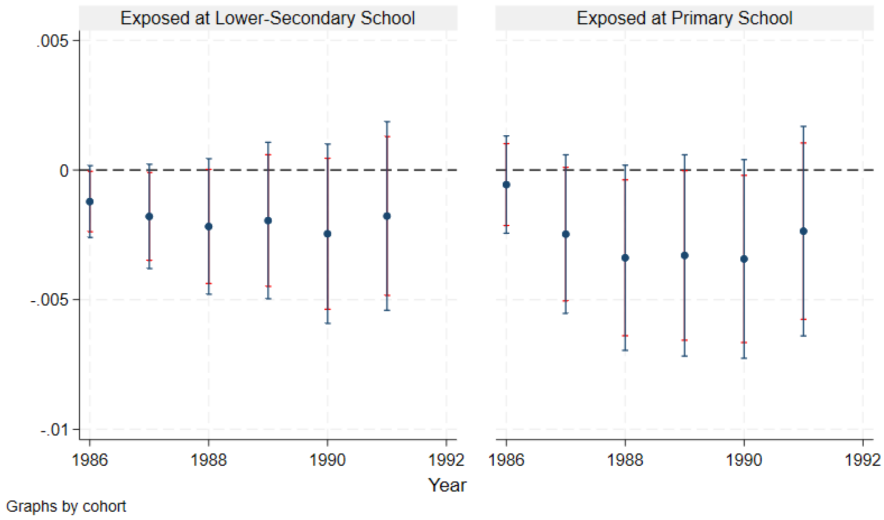
Figure 9: Effect on Earnings, by year of birth



Notes: This figure shows author's estimations from register data generated by Statistics Norway. Calculations are estimates from Equation 4. Instead of using cohort groups, this regression uses each year of birth. Dots represent the π_g estimates; bars represent both 90% confidence intervals, clustered at the municipality level. Sample is restricted to individuals born between 1964 and 1983 who resided in a Norwegian municipality in 1985, which had not changed borders. Annual earnings are measured in dollars, adjusted for 2011 purchasing power parity (PPP), excluding 1st and 99th percentiles.

As discussed in subsection 3.2.3, I first test the likelihood of leaving the municipality in the following years to the reform across municipalities school additional funding. Graph 10, in the appendix, shows the regressions' point estimates and standard errors each year from 1986 to 1991. Students seem to have a slightly lower probability of leaving municipalities receiving higher funding for education. This result is in line with the literature [Gibbons and Silva, 2011; Fredriksson et al., 2016], where it has been found that parents tend to choose schools based on their perceived quality. However, the effect size are considerabely small, below 0.5 percentage points even for cohorts fully exposed to the shock.

Figure 10: Effect on the Probability of Leaving the Municipality, by year



Notes: This figure shows author's estimations from register data generated by Statistics Norway. Calculations are estimates from Equation 5. Dots represent the π_g estimates; bars represent both 90% and 95% confidence intervals, clustered at the municipality level. Sample is restricted to individuals born between 1964 and 1983 who resided in a Norwegian municipality in 1985, which had not changed borders.