Accumulated Instruction Time and Pupil Achievements[§]

Karl Fritjof Krassel[1], Nicolai Kristensen[1,2], Eskil Heinesen[3], Paul Bingley[4]

[1] KORA, Danish Institute for Local and Regional Government Research

[2] IZA, Institute for the Study of Labor

[3] The Rockwool Foundation Research Unit

[4] SFI, Danish National Centre for Social Research

March 2016

Keywords: School Resources, Pupil Achievement, Instruction Time, Pupil Fixed Effects

JEL codes: C21; I2; I21

Extended abstract

The literature on the impact of instruction time on pupils' outcomes is very limited, presumably due to endogeneity issues. Recently, PISA test scores for 15-year-olds combined with student self-reported variation in current instruction time have been used to estimate pupil or school-fixed-effects models utilizing variation across subjects in a given year (Lavy 2015, Rivkin and Schiman 2015). Using only current instruction time ignores that instruction time in earlier years also may affect current outcomes. This will tend to overstate estimated effects of marginal increases in instruction time if instruction time is positively correlated over time within schools. The size of the bias will depend on the size of the correlation, the rate of depreciation of skills and the extent of dynamic complementarity in learning (as stressed by Heckman and co-authors).

Another and perhaps more serious weakness of the data used in Lavy (2015) and Rivkin and Schiman (2015) is that instruction time is self-reported by the individual pupils and that it reflects instruction time attended by each pupil, not instruction time offered by the school. That is, the measure of instruction time is not exogenously given for the individual pupil at a given school which makes interpretation of results difficult. Presumably, less academically ambitious pupils bunk off classes and report few lessons in all subjects. This may be part of the explanation for the very large OLS regression coefficients in Lavy (2015, table 2 and 3). One extra weekly hour of instruction is associated with an increase in test scores of about 0.20 standard deviations. Controlling for pupil fixed effects reduces the effect to about one third (0.06). However, even this estimate may be biased upwards as discussed above. Rivkin and Schiman aggregate outcomes to the school-by-subject-by-grade level, and their estimates are smaller than Lavy's (but still highly significant): The OLS estimate indicates that one more weekly hour of instruction is associated with

[§] Correspondence to Karl Fritjof Krassel, e-mail: kakr@kora.dk, KORA, The Danish Institute for Local and Regional Government Research, Købmagergade 22, DK-1150 Copenhagen K, Denmark. We thank the National Agency for IT and Learning for providing the data on planned instruction time.

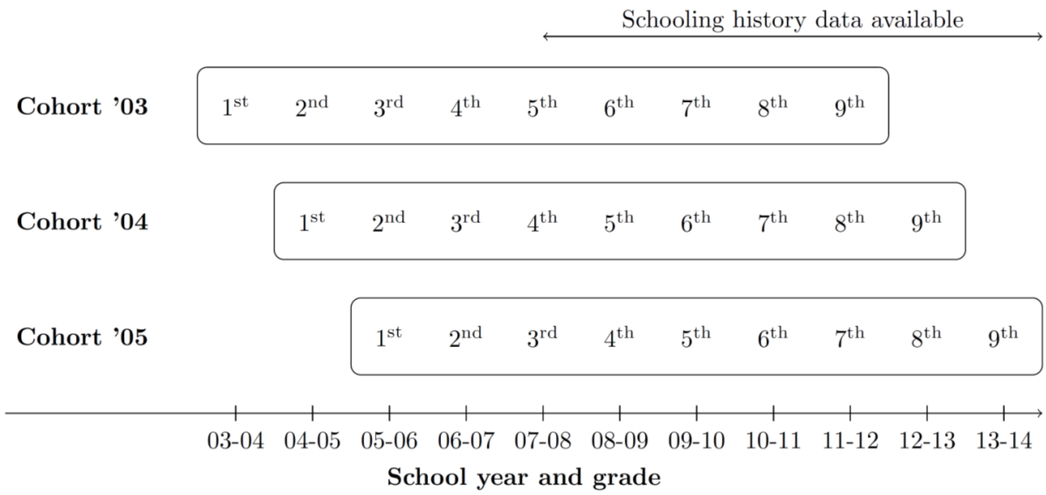
an increase in test scores of 0.087 standard deviations; controlling for school-by-grade fixed effects the estimate is 0.031; and controlling instead for school-by-subject fixed effects it is 0.023.

In this paper, we first demonstrate a somewhat positive correlation in instruction time across years within schools and cohorts. Subsequently, we estimate the impact of instruction time based on accumulated hours following three cohorts of pupils over their entire 9 years of primary and lower secondary school.

Data and sample

As in other countries, the school year in Denmark is staggered to the calendar year. It begins in August and ends in June the following year. Our main explanatory variable is accumulated instruction time and the data window is hence determined by the availability of the planned instruction time. We obtain these data from the Danish National Agency for It and Learning (STIL) under the Ministry of Education for the school years 03/04 – 13/14. We are thereby able to follow three cohorts from 1st grade through to 9th grade. We match data on instruction time with individual level registry data from Statistics Denmark including information on pupils' schooling history, exam grades and socioeconomic background. Figure 1 gives an overview of our cohorts and the data window.

Figure 1: Cohorts and the availability of planned instruction hours and schooling history data



As described further below, we exploit variation in instruction time across subjects (Danish, math and English) to estimate pupil-fixed-effects models. Table 1 shows summary statistics for variables varying by subject. Exam marks have been standardized while our main explanatory variable, accumulated instruction time has been divided by number of school years times school weeks per school year. As the school year consists of 40 weeks, accumulated hours from 1st – 9th grade has been divided by 360, accumulated hours from 1st – 3rd grade have been divided by 120 and so forth. We use various specifications of accumulated instruction time to investigate when instruction time matters the most.

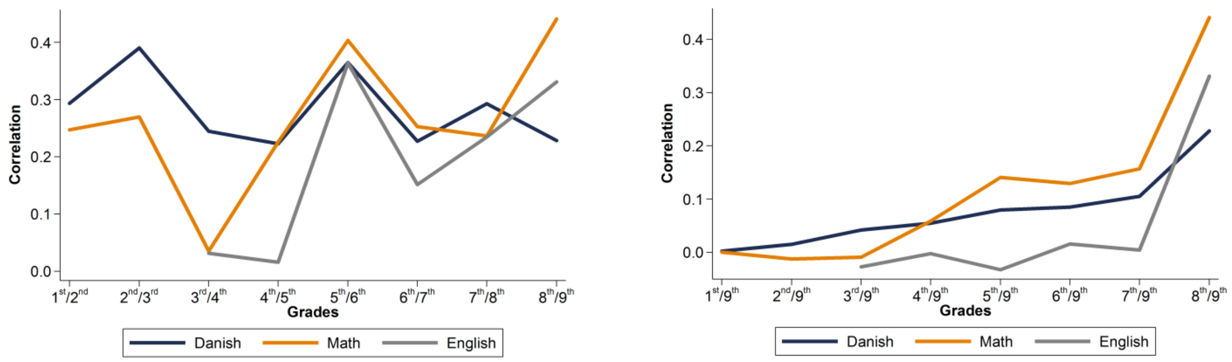
In total, the sample consists of 111,384 pupils from 988 public schools.

Table 1: Summary statistics of variables varying by subject

	Danish		Math		English	
	Mean	SD	Mean	SD	Mean	SD
Standardized exam marks	0.000	1.000	0.000	1.000	0.000	1.000
Weekly hours $1^{st} – 9^{th}$ grade	5.475	0.291	3.308	0.132	1.601	0.074
Weekly hours $1^{st} – 3^{rd}$ grade	7.193	0.636	3.834	0.300	0.500	0.101
Weekly hours $4^{th} – 6^{th}$ grade	4.747	0.450	3.066	0.189	2.028	0.149
Weekly hours $7^{th} – 9^{th}$ grade	4.484	0.206	3.025	0.113	2.276	0.124
Weekly hours 9^{th} grade	4.494	0.281	3.032	0.180	2.299	0.206
Pupils			111,384			
Schools			988			

Figure 2 shows correlation in instruction time across grades for the 2003 cohort. The tendencies are the same for the other cohorts. The correlation in hours between a grade and the consecutive grade varies between 0.0 and 0.3 (Subfigure (a)) with most consistency in Danish. In Subfigure (b) correlation in hours between any grade and 9^{th} grade is depicted showing an almost orthogonal relationship in early grades but stronger correlation in later grades.

Figure 2: Correlation in hours between grades (2003 cohort)



(a): Correlation in hours between a grade and the consecutive grade

(b): Correlation with hours in 9^{th} grade

Model

Consider the model:

$$y_{ijst} = \alpha + \beta h_{ijst} + \gamma X_{ijt} + \delta A_{ijt} + \mu_i + \eta_{st} + \varepsilon_{jt} + u_{ijst} \tag{1}$$

where y_{ijst} is exam marks for pupil *i* of cohort *t* at school *j* in subject *s*, h_{ijst} is instruction time in subject *s* at school *j* for cohort *t*, X_{ijt} is a vector of characteristics of pupil *i* (including parental background variables), A_{ijt} is a vector of variables for school *j* for cohort *t* (e.g. enrolment and class size; it may vary by *i* if some pupils switch school), μ_i is unobserved individual effects, η_{st} is a subject by cohort effect, ε_{jt} represent unobserved characteristics of school *j* for cohort *t*, and u_{ijst} is the remaining error term. Estimation by individual fixed effects (within pupil variation in marks between subjects) takes account of individual and school characteristics (which do not vary by subject), and so the model is reduced to:

$$y_{ijst} = \alpha + \beta h_{ijst} + \eta_{st} + u_{ijst}. \tag{2}$$

We can take account of η_{st} by including subject-by-cohort effects and hence adjusting for variation in the overall mean in exam marks of subject *s* over time.

The pupil-fixed-effects model controls for overall pupil ability which does not vary over subjects. However, it is well known that individual pupils may have rather different abilities in different subjects, e.g. boys tend to have comparative advantage in math and girls in language, and relative abilities in different subjects may also vary by parental socioeconomic variables. We may therefore generalize (2) to allow the effect of X to depend on subject:

$$y_{ijst} = \alpha + \beta h_{ijst} + \gamma^s X_{ijt} D_s + \delta A_{ijt} + \eta_{st} + \varepsilon_{jt} + u_{ijst} \quad (3)$$

where D_s is a dummy variable which is equal to unity if the subject is equal to s and zero otherwise.

Results

Table 2 and Table 3 present selected estimation results. Overall we find, as expected given the literature, positive effects of instruction time on pupil achievement. The difference in the estimate to average weekly hours between columns (1) and (2) in Table 2 highlights the importance of controlling for subject and subject-by-grade effects. Adding controls in column (3) does not change the estimate significantly while excluding pupils who change school during their school career increases the estimate by 56% comparing results in column (3) and (4). The reason we provide an estimate excluding those who change school is that a change could be caused by many different things and might even be endogenous to the instruction time provided by the school. The direction of the bias is hence indeterminable. Providing pupils with one extra hour per week from 1st to 9th grade increases their exam results by 3.4% (or 5.3% given no change of institution) of a standard deviation. This estimate is 10% and 62% higher than the school-by-grade fixed effects and school-by-subject fixed effects respectively found by Rivkin and Schiman but lower than the more comparable pupil fixed effect found by Lavy.

Table 2: Baseline estimation results

	(1) No controls	(2) + Subject and cohort dummies	(3) + Controls	(4) (3) given no change of institution
Weekly hours 1st – 9th grade	0.000	0.032^{+}	0.034^{*}	0.053*
	(0.002)	(0.017)	(0.015)	(0.023)
Danish		-0.119^{+}	-0.287^{***}	-0.407***
		(0.066)	(0.061)	(0.093)
Math		-0.103^{**}	0.001	-0.120*
		(0.035)	(0.038)	(0.047)
Danish × 2003 cohort		0.003	0.002	0.001
		(0.015)	(0.015)	(0.016)
Danish × 2004 cohort		-0.018	-0.017	-0.023
		(0.013)	(0.013)	(0.015)
Math × 2003 cohort		0.121^{***}	0.121^{***}	0.117***
		(0.015)	(0.015)	(0.017)
Math × 2004 cohort		0.023	0.023	0.009
		(0.015)	(0.015)	(0.017)
Controls	No	No	Yes	Yes
R^2	0.651	0.651	0.671	0.667
Observations	334,152	334,152	334,152	220,635

Estimations by pupil fixed effects with observations in Danish, math and English for each pupil. The outcome is standardized exam marks in each subject and control variables are interacted with subject dummies. The standard errors are clustered by municipalities and $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 3 provides results of estimations with various different specifications of accumulated hours. Pupils changing institution have been excluded from the analyses. In columns (1) to (3) only hours in 4th to 6th grade have significant impact on exam marks after 9th grade but the parameter estimate to hours in 7th to 9th grade numerically larger (but insignificant). When adding all hours-related variables together in column (4) hours the picture remains the same and partially suggests that hours in later grades are more important than hours in earlier grades. In column (5) only hours in 9th grade are included and hence corresponds to the fixed-effect estimates in Lavy (2015). The lower estimate suggests that it could be non-trivial to relay on self-reported hours.

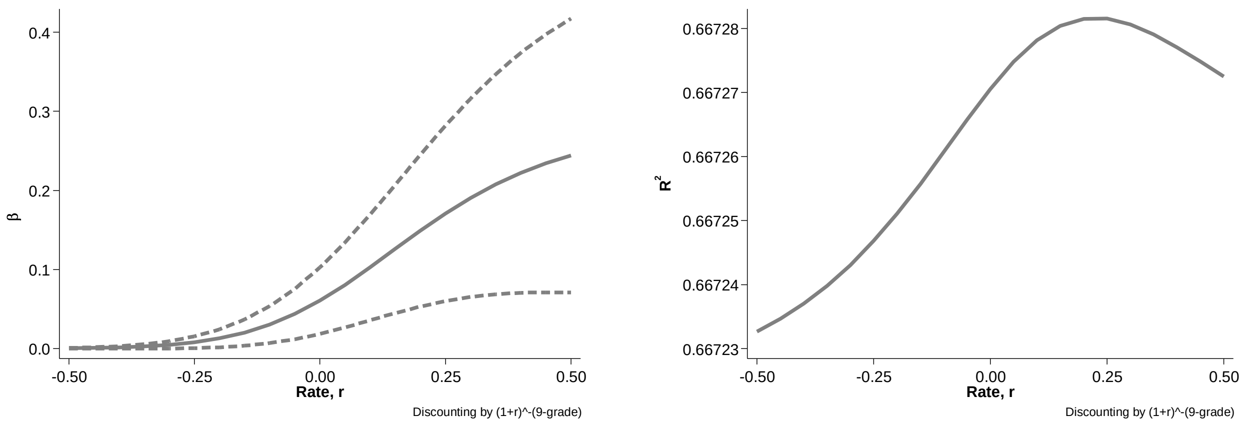
Table 3: Different specifications of accumulated hours

	(1) Hours 1st - 3rd grade	(2) Hours 4th - 6th Grade	(3) Hours 7th - 9th grade	(4) Hours in (1) – (3) all together	(5) Hours 9th grade
Weekly hours 1st – 3rd grade	0.014			0.011	
	(0.010)			(0.010)	
Weekly hours 4th – 6th grade		0.034*		0.029+	
		(0.016)		(0.017)	
Weekly hours 7th – 9th grade			0.047	0.040	
			(0.031)	(0.033)	
Weekly hours 9th grade					0.027*
					(0.013)
Danish	-0.252***	-0.247***	-0.260**	-0.396***	-0.217***
	(0.066)	(0.052)	(0.077)	(0.091)	(0.042)
Math	0.014	0.026	0.026	-0.035	0.041
	(0.046)	(0.045)	(0.041)	(0.049)	(0.039)
Danish × 2003 cohort	0.003	-0.001	0.003	0.001	0.003
	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)
Danish × 2004 cohort	-0.023	-0.025	-0.023	-0.023	-0.023
	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)
Math × 2003 cohort	0.120***	0.120***	0.121***	0.121***	0.121***
	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)
Math × 2004 cohort	0.010	0.011	0.011	0.011	0.011
	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)
Controls	Yes	Yes	Yes	Yes	Yes
R^2	0.667	0.667	0.667	0.667	0.667
Observations	220,635	220,635	220,635	220,635	220,635

Estimations by pupil fixed effects with observations in Danish, math and English for each pupil. The outcome is standardized exam marks in each subject and control variables are interacted with subject dummies. The standard errors are clustered by municipalities and $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

An alternative approach to investigate when instruction time affects achievement the most is to vary the discount factor when accumulating hours and then conduct a grid search. Figure 3 shows the result of the endeavor varying the rate, r, between -0.50 and 0.50 using 0.05 increments. Subfigure (a) shows the parameter estimates while Subfigure (b) shows R^2 from the 21 regressions. The grid search is conducted given no change of institution and hence, the parameter estimate at $r = 0.00$ corresponds to the 0.053 in Table 2 column (4). The parameter estimate increases as r increases as the numerical value of the discounted accumulated hours decreases. Hence, what is interesting in Subfigure (a) is the slope of the tangent to the curve (i.e. the second derivative). The slope is at its highest around 0.20. Though not directly related this is also illustrated in Subfigure (b) where R^2 peaks around 0.20 – 0.25. The interpretation is that instruction time matters the most in later grades as $r > 0$ and hours in earlier grades thereby contribute relatively less than hours in later grades to the accumulated measure. The findings in Figure 3 are hence in line with the findings in Table 3.

Figure 3: Grid search results: $\hat{\beta}_{\text{Weekly hours } 1^{st} - 9^{th} \text{ grade}}$ and R^2



(a): $\hat{\beta}_{\text{Weekly hours } 1^{st} - 9^{th} \text{ grade}}$

(b): R^2

Our results are robust across various alternative specifications: When using year marks as outcome, when including pupils attending feeder schools only covering a limited number of grades and when using only variation across Danish and math (results not shown). In addition, our finding also changes in expected direction (the parameter estimate increases) when we exclude urban municipalities with higher expected inter-school competition.

Conclusion

The existing literature on the effects of instruction time on pupil achievement has some non-trivial design flaws. Using accumulated planned instruction time spanning pupils' whole school career in primary and lower secondary school (1^{st} to 9^{th} grade), this paper improves on the shortcomings and estimate somewhat smaller effects. In addition, the paper finds that instruction time is more important for achievement in later grades compared to earlier grades. The findings are robust across alternative specifications.

Selected references

Lavy, Victor (2015), Do Differences in Schools' Instruction Time Explain International Achievement Gaps? Evidence from Developed and Developing Countries, *The Economic Journal* 125(588): F397–F424.

Rivkin, Steven G. and Jeffrey C. Schiman (2015), Instruction Time, Classroom Quality, and Academic Achievement, *The Economic Journal* 125, 588:F425–F448.