Educational inputs and economic development in end-of-nineteenth-century Prussia

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Abstract

Which role did educational investments play for economic development? Using data on schooling quantity and quality provided by the first and second Prussian census on primary schools and two measures capturing the high and the low end of the income distribution allows applying a value-added approach for industrializing West Prussia. I find that educational investments and in particular teacher unit costs increase income tax per capita substantially while day laborer wages are unaffected. Exploring the sectoral composition of the economy, it is hypothesized that the rising income stems from a shift to higher skilled and higher paid occupations.

JEL-Code: N33, I22; H52.

Keywords: Educational economics, economic development, input output analysis, expendi-tures, Prussian economic history.

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1. Introduction

Towards the end of the nineteenth century, Prussia went through the second phase of the Industrial Revolution. At the same time, the country as a pioneer in primary education expanded its school system ensuring comprehensive school attendance (Lindert, 2004). Little is known, however, about how educational inputs affected ultimate outcomes like earnings—about the educational production process, the input-outcome relationship, and the efficiency of resource use. I hypothesize that higher investments in primary education translated into a higher skilled labor force, illustrated by increasing taxable income where the economy underwent a shift from an agricultural to an industrial economy. In the absence of this sectoral shift, educational investments increase the productivity of workers, measured by day laborer wages.

A large modern literature studies the effects of educational inputs on outcomes in school and later in life finding that all inputs except for school resources matter for later outcomes (e.g., Hanushek, 1986, 2006, 2010). But while there is some historical evidence on how school attendance and literacy relate to returns in the labor market (e.g., Mitch, 1984; Long, 2006), hardly anything is known about how specific school inputs were or were not crucial for the outcomes of the educational production process in a historical perspective. End of nineteenth-century Prussia provides a historical setting with a heavily expanding school system, where class size was huge and deficiencies of school buildings were prevalent with both the quality and quantity of schools varying substantially across Prussia.

This paper estimates educational production functions in a historical context, focusing mainly on Prussia west of the Elbe. Using rich county-level data, it is the aim to estimate how different school inputs in 1886 and 1891 relate to subsequent increases in income. Data on income taxes and day laborer wages allow investigating the effects of educational investments both for the high and the low end of the income and skill distribution.

The approach follows such modern contributions as Card and Krueger (1992a, 1992b), Heckman et al. (1996) and Chetty et al. (2011) in using subsequent earnings as the outcome measure of regionally varying school resources. As is standard in the educational production function literature, a value-added (VA) specification is employed conditioning on initial outcome differences (e.g., Hanushek, 2006). By focusing on changes (rather than levels) in outcomes, time-invariant unobserved factors that relate to both inputs and outcomes are eliminated from the analysis.

In the industrializing West of Prussia, educational investments increase income tax per capita while day laborer wages are unaffected. The effect of educational investments at the high end of the income distribution mainly works through teacher unit costs, going in line with the findings of the literature on contemporary educational production functions stressing the importance of teacher quality for student performance. Infrastructure expenditures are also positively associated with income tax per capita, though to a smaller magnitude.

Hypothesizing that higher skills acquired in primary school allowed people to shift to higher skilled and higher paid jobs, becoming subject to paying income taxes and leaving the segment of day laborers, reconciles the findings on the positive association found for income tax per capita and the null effect found for day laborer wages. This is stressed by additional evidence for Prussia east of the Elbe where the economy remained agricultural, restricting occupational mobility. Consequently, no association between investments in primary education and income tax per capita are detected for East Elbia while day laborer wages are positively correlated with educational spending reflecting a productivity increase in the low-skilled sector.

Section 2 discusses the related literature. Section 3 describes the economic and educational situation in Prussia in the ending nineteenth century. Section 4 introduces the data. Sec-

tion 5 presents the empirical approach, the estimation results and explores possible mechanisms. Section 6 concludes.

2. Related literature

This paper contributes to two strands of the literature. First, it expands the literature on educational production functions to a historical dimension and supports evidence on the importance of human capital for the transition towards an industrial society. Secondly, it speaks to the historical literature on the returns to education. The second strand of literature so far neglects zooming into particular measures of educational quality and quantity such as class size, teacher quality or infrastructure provision.[1]

2.1 The educational production function

The literature on the educational production function was triggered off by the Coleman report on Equality of Educational Opportunity investigating the relationship between educational inputs and output in the US with the aim to analyze the effect of school quality—measured first of all by class size—on student achievement (Bowles, 1970; Hanushek, 1979, 2003).

The early literature used test scores as an immediate outcome of educational inputs. Test scores are not available in the historical context of nineteenth-century Prussia, requiring another measure of student performance. The literature examining current educational production functions started looking at long term outcomes of educational inputs by examining performance in the labor market, mostly measured by later earnings. These long term measures allow capturing whether skills acquired in school eventually translated into higher labor market success and might therefore be considered as the more encompassing measure for educa-

[1] The underlying idea of the paper that human capital fosters economic development and is indispensable for the transition phase to self-sustaining growth goes back to the growth model developed by Lucas (1988). Empirically, Mitch (1999) provides counter evidence for England as the first industrializing nation where formal education was unessential for economic growth. In the context of Prussia, Becker, Hornung and Woessmann (2011) show that basic education mattered for Prussia's industrialization as the country was a technological follower of the First Industrial Revolution which made basic skills a requirement to adapt technological innovations made by the industrial pioneer England. As this paper focuses on the particular inputs in the education process, the extensive literature following from this theory and its empirical response is not discussed here.

tional outcomes. The approach in this paper hence follows such modern contributions as Card and Krueger (1992a, 1992b), Heckman et al. (1996), and Chetty et al. (2011) in using subsequent earnings as the outcome measure of regionally varying school resources.

The modern literature does not provide consensual evidence on which school resources have a significant impact on subsequent earnings (Todd and Wolpin, 2003). The overall consensus that can be derived from the modern empirical literature is that additional educational spending does not automatically improve the quality of schooling and school outcomes, but that it is teacher quality that matters for student's performance.[2] The effects of a high-quality teacher on student's performance are large. Being taught by a teacher near the top of the quality distribution translates into one year's worth of additional learning.

2.2 Historical evidence on educational inputs and economic development

But do these findings also hold for a time when compulsory schooling had just been achieved, when it was common that teachers in the countryside had to handle 140 to 170 students at a time (Tews, 1914), when the lack of school buildings and teachers was severe due to population increase and internal migration and therefore considered as one of the main challenges by the Prussian Ministry of Ecclesiastical and Education Affairs (Königliches Statistisches Bureau in Berlin, 1908)?

There are only few empirical studies examining the impact of educational resources in primary schooling on ultimate outcomes from a historical perspective and all of them focus on England. Mitch (1984) looks at the changes in the rate of return to literacy after an increase in government involvement in primary education, finding that the return to male literacy de-

[2] Studies which causally evaluate the impact of teacher quality on student's performance measure teacher quality by student's improvement in test scores. By controlling for initial students' test scores, the improvement in subsequent test scores is attributed to the teacher's quality, the so-called teacher's value-added. Koedel, Mihaly and Rockoff (2015) review the literature on the value-added approach, discussing the draw backs of the approach. In linking school district and tax records, Chetty, Friedman and Rockoff (2014a, 2014b) are able to control for detailed information on students and their families at great detail showing that student's prior test scores are indeed able to provide unbiased forecasts of teacher's impacts on student achievement and have a substantial effect on students' lifetime earnings.

creases once the English government started to compensate for underinvestment in literacy. Long (2006) examines the impact of school attendance on adult labor market outcomes in Victorian England by looking both at occupational mobility from one generation to the next and on associated wage gains. He finds a small positive effect in terms of occupational mobility and a relatively small effect of education on earnings.

Lundgreen (1976) relates education and economic growth for nineteenth-century Prussia, finding that education had only little impact on income growth by estimating a classical production function and using public expenditures on education and enrolment rates in order to measure the amount of schooling. However, he uses time series data not exploiting the variation across Prussian counties and does not further decompose public expenditures into single inputs of the educational production function. Becker, Hornung and Woessmann (2011) examine the effect of primary education on economic growth for the nineteenth century when Prussia underwent the first and second phase of the Industrial Revolution. Linking school enrollment data with factory employment data, they find that primary education and non-textile industrialization are positively associated. They hypothesize that basic education was important for Prussia's economic catch-up as the country was a technological follower of the Industrial Revolution. This paper takes this further by examining which specific educational inputs mattered for economic development and by stressing that human capital mattered for the transition to an industrial society.

3. Historical background

At the end of the nineteenth century Prussia experienced an economic boom through the second phase of the Industrial Revolution granting higher tax income for the state and the municipalities. Simultaneously, the primary educational system expanded both quantitatively and qualitatively. However, the industrial progress did not take place evenly across Prussia, but expanded from the North West of Prussia (Kuhlemann, 1991), generating mass migration

from the eastern to the western parts of Prussia, assuring an ample supply of labor in the West.[3] Therefore, this analysis focuses on the industrializing Prussian regions west of the river Elbe.

The provinces in the East of Prussia which were still heavily relying on the agricultural sector[4] lacked a demand for workers who were able to read, write and do calculus, i.e. for cognitive skills delivered by primary school. Furthermore, many people in the East of Prussia remained illiterate despite having attended school (Glück, 1979). In the agricultural regions of Prussia, the primary school was even considered as an institution impeding the economic progress of those regions and suppressing the capacity of municipalities by burdening them with funding the educational system (Kuhlemann, 1991).

3.1 Economic development

Undergoing the second phase of the Industrial Revolution, Prussia's economy faced a fundamental structural change with the emergence of the chemical and electrical sector (Hahn, 2005).

According to the narrative of economic history, the Second Industrial Revolution relied on the steady accumulation and diffusion of useful knowledge and therefore meant technological progress on a scientific basis—as opposed to the First Industrial Revolution where industrialization was unaffected of basic education (Mokyr, 1999).

Large economies of scale, the electrification of production processes and interchangeable parts' technology culminated in standardized mass production, leading to the emergence of large-scale firms. The labor force was segmented into skilled well-paid supervisory personnel and unskilled low-paid ancillary personnel that could easily be substituted (Ullmann, 1980). Besides this segmentation of the labor market, a new group, the white collar workers,

[3] While the population west of the river Elbe grew at a rate of 15 percent between 1885 and 1900, it grew at only 7 percent in the regions east of the river Elbe.

[4] The low level and variation of income tax per capita in Prussia east of the Elbe is illustrated in Figure 3.

emerged, carrying out clerical tasks emerging from the more interdependent work flows in large-scale firms. With an increasing demand for investments in new technologies, the banking sector became indispensable to assure access to capital (Kocka, 2002).

This structural change in the economy changed the relative demand for skills, i.e. for educated workers, and the technological progress simultaneously raised the return to human capital investments. As explicated above, Becker, Hornung and Woessmann (2011) already demonstrated the importance of human capital embodied in primary education for Prussia's economic catch up.

Urban primary schools in particular provided students with a solid knowledge base to continue with an apprenticeship and consequently work as skilled laborers (Geissler, 2011). As wages depended on the kind of education and formation, skilled craftsmen and technicians earned substantially more than unskilled workers.

3.2 The educational system and economic development

Prussia's educational system had been bipartite until the advancement of the Second Industrial Revolution made industrial stakeholders realize the increased demand for technical and applied skills and advocate for vocational and technical education (Schütte, 2003). Before this, children from the lower social strata attended the extended primary school which encompassed students from age six to 14 (Neugebauer, 1992) releasing them to low-skilled and low-paid jobs, while children from the upper tail of the social strata attended *Gymnasium* which was the only educational institution granting the right to attend university and consequently granting access to high-paid and high-status jobs.

As Prussia had built her educational system after the Napoleonic defeat of Jena in 1806, one of the main aims of primary education was to educate a strong military which resulted in molding loyal subjects of the state (Hage, Garnier and Fuller, 1988). Even though the curriculum introduced by the General Regulations of 1872 shifted the contents to more applied sub-

jects such as geometrics and social studies (so-called *Realien*), the bigger part of the curriculum remained being devoted to subjects such as German and religion which rather aimed at socializing the students than teaching technical and applicable skills (Lamberti, 1989).[5] It was only with the Second Industrial Revolution that industrial stakeholders started to lobby for the introduction of more applied schools such as continuation and vocational training schools finally granting alternative educational paths to graduates of extended primary education (Schütte, 2003).

The Prussian primary educational system itself experienced a public expansion of schooling from 1861 onwards which Lundgreen (1976) argues to be captured by total expenditures for education. The increasing investments in education resulted in a decline of the student-teacher ratio and an increase of teachers' salaries, both indicators of a quality change of educational services.

As there was no universal legal framework for the funding of primary schools on state-level until 1906, the levels of investments in primary education varied widely across Prussia (Wittmütz, 2007). The funding of primary schools was primarily left to the local authorities such as the municipalities and large landowners while the state came up for educational expenses when local authorities failed to cover educational costs. In 1886, about 88 percent of educational spending for primary schools came from local sources. Given the local structure of school funds, Lindert (2004) depicts the educational expansion as a result of a spontaneous political will. Expenditures on primary education made up about 20 percent of a municipality's annual budget and therefore implied the greatest shift of resources from the upper income groups to the poor (Lindert, 2004).

Due to the local funding of the primary schools, the quality of schooling differed widely across Prussia. The widest gap was observed between the urban and the rural areas – and be-

[5] The function of the primary school in conveying a national ideology in the context of Prussia at the turn of the 20th century and the literature related to education and indoctrination is discussed in Cinnirella and Schueler (2016).

tween the East and the West (Neugebauer, 1992). While the single-class school was predominant in the countryside with one teacher teaching all levels and ages of students, multiple-class schools allowed for differentiation between levels and ages of students in the cities (Kahlert, 1978). Urban schools were in general better equipped than rural schools. However, they had to react to the influx of students through the ongoing urbanization and the general population growth. Urban schools could not expand their capacities as fast as people were moving to the cities. But also teachers rather moved from the countryside to the cities, deteriorating the existing shortage of teachers in the countryside and especially in economically underdeveloped regions (Kuhlemann, 1991).

Even though class size was legally limited to 80 students in single class schools and 70 students in multiple class schools respectively, these limits were rather desired than achieved being particularly excessed in the Rhineland—and also in the East of Prussia (Tews, 1914).

The historical debate on school resources in Prussia mainly focused on the importance of reducing class size which was considered a quality standard for schooling and was understood as the main condition for the mass expansion of education. The shortage of school buildings and other school facilities was also addressed in the contemporary pedagogical debate (Kahlert, 1978). However, increasing teacher's quality by e.g. standardizing teacher's education was partly opposed by government authorities as primary school teachers were feared to gain too much influence in the society once obtaining a certain level of education (Kuhlemann, 1991).

4. Data

This paper uses data on 217 counties in West Elbian Prussia, mainly stemming from the ifo Prussian Economic History Database (iPEHD).[6] In section 5.6, I will expand the analysis to East Elbia, examining a sample of 235 counties.

[6] For a detailed description of the iPEHD, see Becker et al. (2014).

4.1 School inputs

The Royal Statistical Office of Prussia conducted its first education census on primary schools in 1886 containing rich information on the school environment, teacher's quality and student inputs. From 1886 to 1911 the census is conducted every five years providing a systematic and consistent longitudinal dataset on educational inputs. As data on the outcome variables—income tax per capita and day laborer wages—is only available at two points in time and I expect a time lag of about 15 (10) years until the acquired human capital in primary school fully unfolds, I will use data from the education censuses for the years 1886 and 1891.

In order to examine the efficiency of resources used for primary schools, I will examine total expenditures per student to capture the overall investments into the educational system. In a second step, the teacher-student ratio, teacher unit costs, and infrastructure expenditures per student will be looked upon. Similar to class size, the teacher-student ratio will capture the provision of teachers. Teacher unit costs denote the log teacher wages per teacher. As teacher wages at this time already depicted quality differences with teachers of low-quality schools (e.g. so-called *Küsterschulen*) earning less than ordinary teachers, I consider teacher wages as a measure of teacher quality following the contemporary literature on educational production functions. Infrastructure expenditures per student comprise the expenditures for the construction, enlargement and maintenance of school buildings. As can be seen in Table 1, teacher salaries made up for the bigger part of educational expenditures. As discussed above, the teacher-student ratio was already considered as a standard for school quality by contemporaneous observers (Kahlert, 1978). As insufficient school buildings lacking a decent aeration and windows hampered the learning conditions, investments in infrastructure will be looked upon as third component capturing the school environment.

4.2 Measuring economic development

Following the modern literature as Card and Krueger (1992a, 1992b), Heckman et al. (1996) and Chetty et al. (2011), subsequent earnings are used as an outcome measure of the educational production function. Prussian county-level data provide two measures to capture subsequent earnings. Income tax per capita grasps both the skilled high end of the income distribution and includes income from rents, unaffected of human capital attainment.[7] Assuming that income from rents is rather stable over time, I expect increases in income to be ascribed to increases in high-skilled labor in the first place. At the low end of the income distribution, day laborer wages provide a measure of returns to unskilled labor. Both, income tax per capita and day laborer wages are available at two points in time, allowing for a value-added approach, introduced below.

As people were only liable to income taxes if they exceeded an annual income threshold of 900 marks, low-income households were naturally exempted from paying income taxes (Hill, 1892). The municipal tax statistics of 1883/84 provide data on income taxes for the respective year. The *Festschrift* on the occasion of the centenary of the Royal Statistical Office of Prussia published a volume containing income tax receipts and the total number of income tax payers covering all Prussian counties (averaged over the tax years 1899 through 1903).[8] The available data on income tax per capita are therefore measured both before and after educational inputs are measured in 1886. The time lag of 15 years between the educational inputs and the output allows the student cohort of 1886 to continue education and acquire relevant experience to pay off in the labor market. The timeline of the data is illustrated in Figure 1.

[7] More precisely income taxes were constituted of 1. investments from capital; 2. income from real estates; 3. profits or earnings from trades, industries and mines; 4. wages, salaries, professional earnings, or pensions, annuities, or other sources of periodical income (Hill, 1892).

[8] In the following, I will refer to the year 1901 for income tax per capita as this denotes the average year between 1899 and 1903.

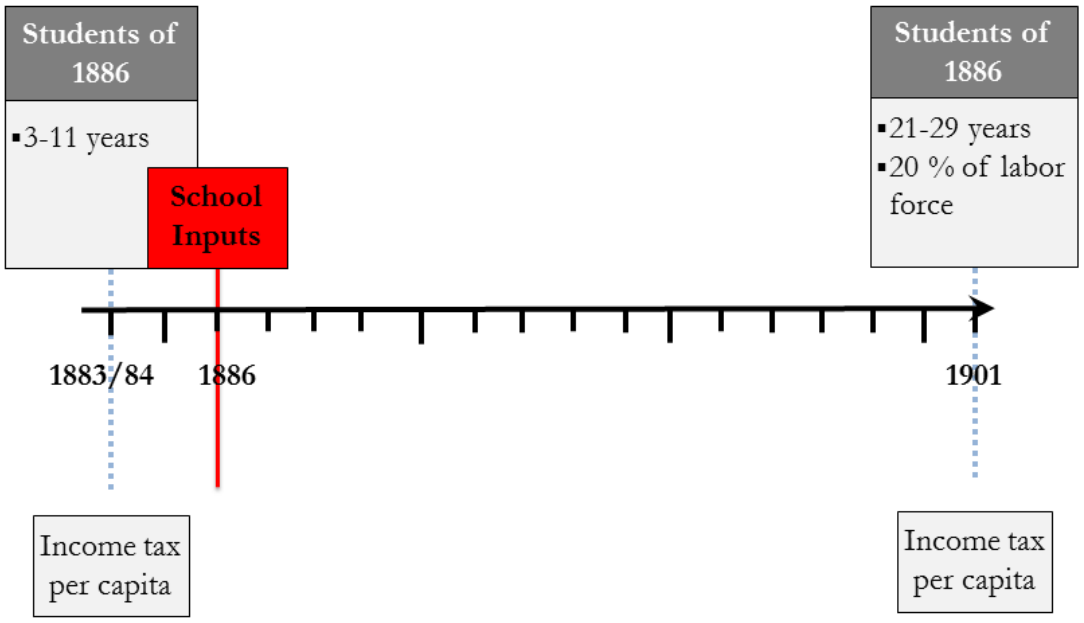


Fig. 1. Timeline for data with school inputs of 1886 and income tax per capita in 1883/84 and 1901
Note: Own illustration.

The second measure for returns to primary education is wages of low-earning households that are not subject to income taxation, so-called day laborer wages. These data are available from the Social Security Statistics in 1892 and 1901 (from Neuhaus, 1904). It was levied because an amendment of the Health Insurance Law made contributions to the Health Insurance System a constant fraction of the customary wage paid to day laborers in each county. This illustrates the representativeness of these wages for low-income households by the Prussian authorities making them a useful proxy for the local standard of living of the low-wage earnings segment (Becker and Woessmann, 2009).

The data were collected at the municipality level which is why it is available separately for urban and rural municipalities. It is furthermore subdivided by men and women and by workers below and above the age of 16 years. As 75 percent of the labor force were male (Lundgreen, 1976), I will look at the average of the earnings of urban and rural male workers over 16 years, weighted by the urban and rural share of the population of each respective

county, in the baseline specification.[9] As the education census also reports data separately for rural and urban parts of each county, I will look at the urban and the rural sample separately in a second step.

Measuring day laborer wages of men over 16 years in 1892 assures that the student population of 1891 is not contributing to the work force yet as the student population of 1891 is still under 16 years old. Ten years later, in 1901, the student cohort of 1891 fully contributes to the labor market and constitutes roughly 20 percent[10] of it. Ideally, one would like to observe only the wages of the student cohort attending school in 1891 which would require data on day laborer wages that can be further split up by specific age cohorts. Measuring earnings in 1901 would require data for day laborer workers between 16 and 24 years. Using day laborer wages for men over 16 years meets the restriction of the minimum age, but unfortunately data do not permit restricting wages to workers below 24 years. The timeline of the data is illustrated in Figure 2.

In order to understand the underlying mechanisms on how the embodied human capital might have led to higher economic development, I furthermore investigate changes in the sectoral composition of the economy. Therefore, I use data from the occupation censuses of both 1882 and 1895. The occupation censuses distinguish between the agricultural sector; the manufacturing sector including mining, construction, the manufacturing of metals, machinery, equipment, chemicals, textiles, paper, leather, food products, and wood; the service sector including trade business, insurance, transport, lodging, and restaurants; the domestic service sector constituted of servants and housemaids;[11] the public administration and military sector

[9] Results are robust to using earnings of urban male workers over 16 years and rural male workers over 16 years separately. Results are not shown, but available upon request.

[10] This is a rough measure, derived from dividing the student population of 1891 by the total population between 14 and 69 years in 1900, thereby assuming that all students survived to working age and that the share of the respective student cohort and of the overall population not entering the active work force are the same. Lundgreen (1976) defines the workforce as the population between 14 and 69 years.

[11] In the occupation census of 1882, domestic servants (*Dienstboten*) were reported in a separate category. Data on the domestic service sector and domestic servants will be therefore merged into one category.

and the sector constituted of people without employment. As described in section 1, the Second Industrial Revolution implied a shift to the electrical and chemical sector (comprised in the manufacturing sector) and to clerical work (captured by the service sector). When approaching possible underlying mechanisms of investments in primary education and economic development in section 5.4, I will test which sector benefitted from higher investments in education.

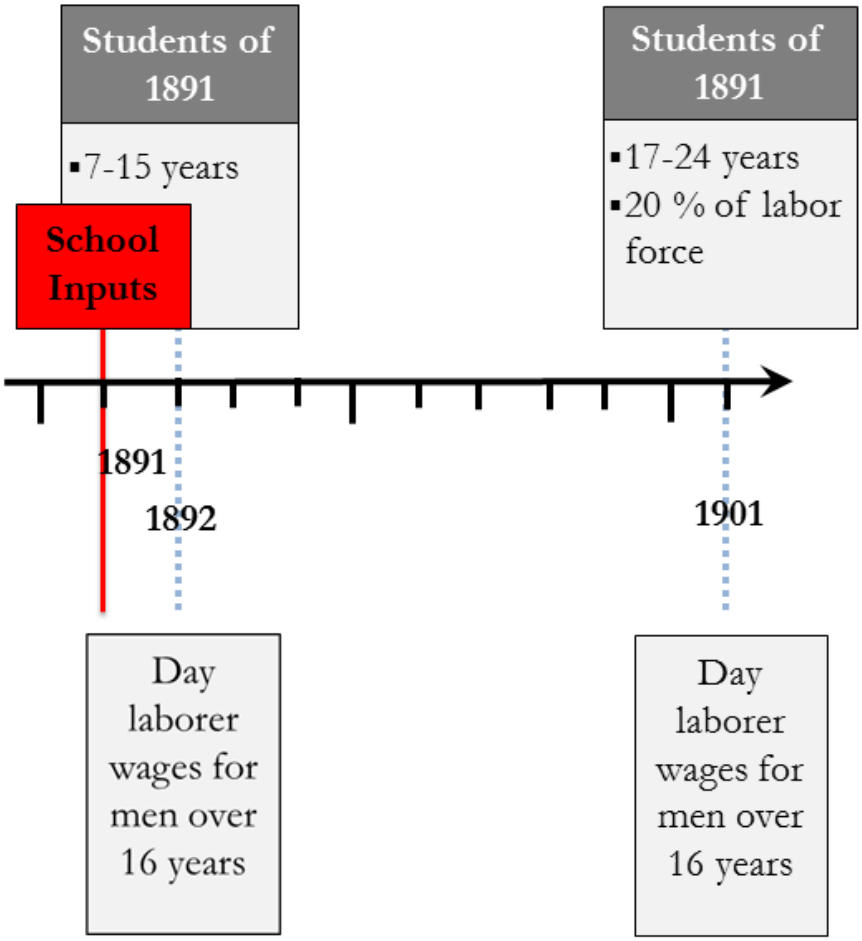


Fig. 2. Timeline for data with school inputs of 1891 and day laborer wages of 1892 and 1901
Note: Own illustration.

4.3 Controlling for demographic and developmental characteristics

For the control variables, data from the occupation census of 1882 and from the population census of 1885 and 1890 are used. Besides the educational inputs, demographic factors and other county characteristics can have an impact on income and earnings differences. As

Becker and Woessmann (2009) found that Protestant counties were more prosperous than Catholic counties through a higher demand for education, the share of Protestants is controlled for. A higher share of females is expected to lower income tax per capita as women usually did not participate in the first labor market where income tax was generated. Concerning earnings in the low income sector, female workers who received lower earnings on average, might have decreased the demand for male labor and therefore decreased male day laborer earnings. As Cinnirella and Hornung (2016) find that landownership concentration which is used as a proxy for the institution of serfdom has lowered school enrollment in nineteenth-century Prussia, landownership concentration is included as a control, even though the authors show that the effect of landownership concentration diminishes towards the end of the nineteenth century. As the presence of the landed elite was especially high in agricultural regions, a high level of landownership concentration is expected to lower both income tax per capita and day laborer wages.

In order to account for previous developments, the growth rates of the respective covariates for the period between 1885 and 1900 for income tax per capita and for the period between 1890 and 1900 for day laborer wages are equally considered.

Furthermore, I include possibly endogenous covariates in order to conservatively control for other confounding drivers of development. As cities are known to generate higher income and wages, the share of people living in cities is included. In order to account for the shifts in the sectoral composition, going back to the second phase of the Industrial Revolution, the share of workers employed in the manufacturing sector measured in 1882 is also considered. Income taxes were levied per household which is why the average household size is included additionally. As people migrated to the more industrialized regions of Prussia in order to find work, the share of people who ever migrated across localities or beyond is included as well. Finally, the share of primary education funds stemming from municipal sources (taxes) is

considered in order to account for the fiscal capacity of the municipalities. Again growth rates for these possibly endogenous covariates are accounted for in an ultimate estimation specification.

4.4 Descriptive statistics

As can be seen in the descriptive statistics in Table 1 as well as in Figure 3, there is a huge variation in income tax per capita both in 1901 and 1883/84. The overall trend shows rising

Table 1

Descriptive statistics 1885/1886 and 1890/1891

	1885/1886				1890/1891			
	Mean	Std. Dev.	Minimum	Maximum	Mean	Std. Dev.	Minimum	Maximum
Income tax per capita 1901	3.814	3.069	0.810	24.389				
Income tax per capita 1883/84	1.756	1.214	0.328	11.219				
Day laborer wages 1901					2.026	0.319	1.500	3.100
Day laborer wages 1892					1.741	0.268	1.250	2.677
Employed in sector *(share) 1882 and 1895*								
Agriculture	0.427	0.188	0.005	0.761	0.415	0.199	0.005	0.765
Manufacturing	0.331	0.136	0.114	0.718	0.357	0.148	0.113	0.741
Service	0.068	0.034	0.024	0.242	0.085	0.041	0.027	0.273
Domestic services	0.083	0.031	0.020	0.239	0.014	0.011	0.001	0.073
Military	0.042	0.037	0.014	0.274	0.048	0.041	0.017	0.317
Without occupation	0.050	0.027	0.010	0.165	0.080	0.031	0.020	0.217
Expenditures p. stud. (in Mark)	23.624	7.463	14.364	79.461	28.685	7.565	16.687	79.751
Teacher-student ratio (x 100)	1.446	0.205	1.018	2.063	1.367	0.196	0.950	2.080
Teacher unit costs (in 1.000 Mark)	1.145	0.188	0.833	2.471	1.280	0.165	0.984	1.942
Infrastructure exp. p. stud. (in Mark)	7.981	4.707	3.312	48.309	10.198	4.969	4.127	49.483
Personnel expenditures (share)	0.676	0.074	0.392	0.841	0.655	0.068	0.380	0.803
Infrastructure expenditures (share)	0.324	0.074	0.159	0.608	0.345	0.068	0.197	0.620
Protestant (share) 1885 and 1890	0.563	0.397	0.003	0.995	0.562	0.394	0.005	0.996
Females (share) 1885 and 1890	0.504	0.013	0.464	0.552	0.504	0.014	0.461	0.552
Landownership concentration 1882	0.002	0.003	0.000	0.030	0.002	0.003	0.000	0.030
Urbanization (share) 1885 and 1890	0.315	0.249	0.010	1	0.315	0.251	0.010	1.000
Average household size 1885 and 1890	4.863	0.328	3.848	5.607	4.853	0.345	3.806	5.656
Movers (share) 1885 and 1890	0.345	0.111	0.148	0.635	0.348	0.113	0.142	0.634
Municipal contributions (share)	0.237	0.109	0	0.583				

Note: The samples of 1886 and 1891 contain 217 observations for West Elbia. If not indicated otherwise, years refer to 1886 and 1891. See Appendix for data sources and details.

income tax per capita and an increasing gap between low and high income counties over time with average income tax per capita doubling between 1883/84 and 1901. Figure 3 illustrates the variation of income tax per capita across Prussia in 1901 and again motivates why this paper focuses on the West of Prussia as variation in income tax per capita in the East of Prussia is very low.

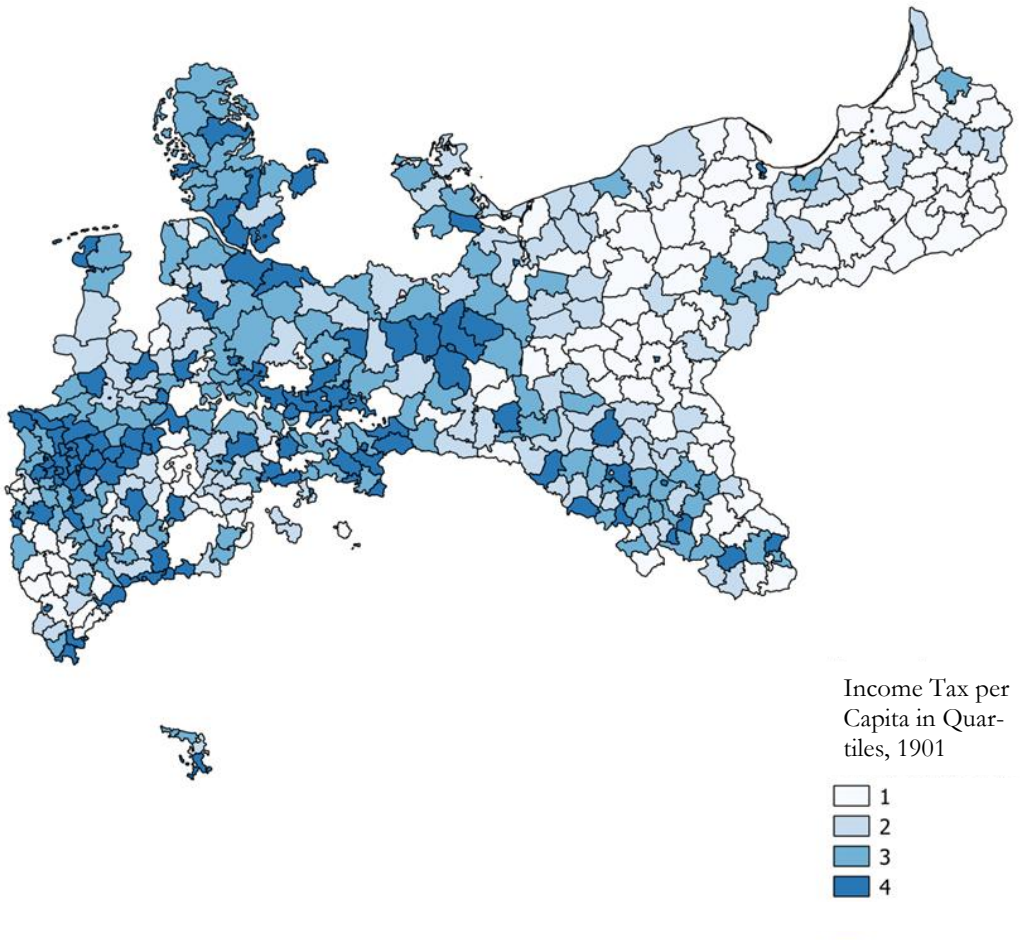


Fig. 3. Income tax per capita in 1901
Note: Income tax per capita is constructed as the sum of income taxes over the total population. County borders as in 1871. Source: Own illustration; see main text for details.

The variation of day laborer wages is lower than the one in income tax per capita and does only slightly increase over time. Concerning the sectoral composition of the economy, a shift away from the agricultural sector and domestic services to the service sector can be observed. More than two thirds of educational investments are devoted to teachers. Huge varia-

tion across counties is found in all focal variables, i.e. in expenditures per student; the teacher-student ratio, teacher unit costs and infrastructure expenditures per student.

5. Estimating an educational production function

First, descriptive evidence is derived from an ordinary least squares (OLS) model. OLS models always run the risk of missing out to account for other confounding factors, not captured by the control variables, and might be biased due to reversed causality. In this specific context, economic development might also be affected by past infrastructure investments of a county which facilitates economic progress. Spill-overs of past growth might equally affect economic development at the time of observation. Reversed causality might arise from the fact that prosperous counties might invest more into their educational system than less developed counties. Even though expenditures for primary schools mainly stemmed from local sources and hence not from income taxes, local revenues and income taxes of a respective county are still very likely to be correlated. In order to account for the biases evolving from both omitted variables and reversed causality, a value-added approach (VA) is introduced in section 5.2, accounting for past investments in the educational system and a county's infrastructure in general as well as for historical growth paths.[12] The VA specification allows controlling for the initial situation in each county by including the lagged outcome variable in the estimating equation. The key assumption for a VA specification is that the lagged outcome variable is a sufficient statistic for historical inputs and also captures endowments such as county-specific economic and general conditions (Todd and Wolpin, 2003). As the development of basic education in Prussia had developed at the local level controlling for the lagged

[12] Data on educational investments in 1868/69 for the estimations on income tax per capita and 1883 for estimations on day laborer wages would allow for a first difference model. The earliest data measuring educational investments, published by the Royal Statistical Office, are, however, available for 1882. The data of 1882 would allow for a first difference model for day laborer wages, though not for income tax per capita. In the sake of comparability, I resign from applying a first difference model to day laborer wages. A panel model with county fixed effects differencing out time-invariant unobservable characteristics of a county cannot be applied as the outcome variables are only available at two distinct points in time.

outcome variable and thereby looking at the change in the outcome variable instead of the level allows estimating the contribution of educational inputs on economic development more precisely.

The acquisition of human capital is generally considered as a cumulative process (Todd and Wolpin, 2003). This does not only yield for the individual, but also for the acquisition of education at the aggregate county-level. Providing the population with education is easier, once educational institutions such as schooling laws and their enforcement have been established, school buildings have been built and the provision of high-quality teachers is ensured. By including the lagged outcome variable the VA approach cannot only capture past educational investments of a county, but is also able to control for its natural advantages (Hanushek, 1997). However, the approach still bears the risks of biases which will be discussed in section 5.2.

5.1 OLS model and results

In order to estimate the returns to educational inputs, descriptive evidence is derived from OLS estimates. The following estimation specification is estimated:

$$ogY_i = \alpha + \beta e_i + X'_i\gamma + \alpha_p + \varepsilon_i \qquad (1)$$

where Y_i indicates income tax per capita in 1901 or day laborer wages in 1901, respectively. i denotes county. β is the coefficient of interest. e denotes the different educational inputs. First, overall expenditures per student will be looked upon. In a second step, the teacher-student ratio, teacher unit costs and infrastructure expenditures per student are used simultaneously in order to examine which association withstands while holding the other input variables constant in a kind of horse race approach. X' is a vector of control variables including the share of Protestants, the female share and landownership concentration. Furthermore the

growth rates of these variables between 1885 (1890) and 1900 are included and province-fixed effects α_p for six provinces are included in order to look at differences within a province.[13] Finally, possibly endogenous controls such as the urban share, the average household size, the share of workers employed in manufacturing, the share of people who migrated across locality borders and the share of funds provided by the municipality are included in the estimation, again being complemented by the growth rates of these possibly endogenous covariates over the period 1885 (1890) and 1900. ε_i indicates the error term. Both, the outcome variables and the focal input variables with the exception of the teacher-student ratio are included as logarithm which allows interpreting the coefficients as elasticities.

Table 2 shows results of the OLS estimations. As shown in Columns 1 to 4, overall expenditures per student correlate positively and significantly with income tax per capita throughout all specifications. The coefficient decreases by more than half once the possibly endogenous controls are included in Column 3.

In the preferred specification including county-specific growth rates and province-fixed effects (Column 2), increasing expenditures per student in 1886 by 10 percent correlates with 17 percent higher income tax per capita. Given that the share of the labor force in 1901 going to primary school in 1886 and therefore benefitting from educational expenditures in 1886 made up only about 20 percent of the labor force in 1901,[14] this coefficient is substantially high. However, at the moment only correlations are looked upon and the result could also be driven by the fact that richer counties invested more in education which will be addressed in section 5.2.

[13] I also included the standard controls, the corresponding growth rates and the province-fixed effects successively in three separate estimations. As the coefficients of these estimations do not alter substantially, these specifications are not shown.

[14] This is again based on the assumption that the labor force is constituted of all male and female individuals between 14 and 69 years old (Lundgreen, 1976).

Table 2

Economic development and spending on education: OLS estimates

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dep. Var.:	Income tax per capita 1901 (log)				Day laborer wages 1901 (log)			
Expenditures p.	1.697***	1.712***	0.657***	0.660***	0.306***	0.342***	0.128***	0.096**
stud. (log)	(0.089)	(0.096)	(0.241)	(0.222)	(0.042)	(0.039)	(0.044)	(0.040)
Protestant		0.059	0.020	-0.017		0.005	-0.030	-0.044
		(0.104)	(0.078)	(0.079)		(0.039)	(0.030)	(0.031)
Female		-1.813	-1.541	-0.434		-2.477***	-0.810	-1.106*
		(2.612)	(2.322)	(2.213)		(0.757)	(0.662)	(0.617)
Landownership		-0.144	-4.958	-10.995		-7.937	-3.842	-4.252
concentration		(11.865)	(7.989)	(7.953)		(6.143)	(5.944)	(3.845)
Urbanization			0.982***	0.924***			0.056	0.020
			(0.167)	(0.153)			(0.046)	(0.042)
Average.			-0.064	-0.080			0.010	-0.027
household size			(0.111)	(0.107)			(0.038)	(0.035)
Employed in			0.298	0.374*			0.408***	0.327***
manufacturing			(0.202)	(0.225)			(0.064)	(0.069)
Movers			1.514***	2.036***			0.472***	0.261**
			(0.404)	(0.417)			(0.125)	(0.129)
Municipal con-			0.201	0.042				
tribution			(0.224)	(0.212)				
Exogenous GR	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Province FE	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Endogenous GR	No	No	No	Yes	No	No	No	Yes
Observations	217	217	217	217	217	217	217	217
R-squared	0.50	0.56	0.75	0.79	0.20	0.44	0.64	0.68

Note: OLS estimates. The dependent variable is the logarithm of income tax per capita in 1901 in Columns 1 to 4 (and the logarithm of the average male day laborer wages over 16 years in 1901 in Columns 5 to 8). The variable of interest, expenditures p. stud. (log) is the log of total expenditures per student in 1886. Protestant denotes the share of Protestants in 1885 (1890). Female denotes the share of females in 1885 (1890). Landownership concentration denotes the share of farms larger than 100 ha arable land in 1882. Urbanization is the share of people living in cities in 1885 (1890). Average household size is the average number of people living in private households in 1885 (1890). Employed in manufacturing denotes the percentage of workers employed in manufacturing in 1882. Movers denote the share of people born in another locality than their resident locality in 1885 (1890). Municipal contribution denotes the share of primary expenditures, contributed by the municipality in 1886. Exogenous GR include the growth rates of 1) the Protestant share between 1885 (1890) and 1900, 2) the female share between 1885 (1890) and 1900, 3) landownership concentration between 1882 and 1895. Province-fixed effects are for six provinces. Endogenous GR include the growth rates of 4) the share of people living in cities between 1885 (1890) and 1900, 5) the population between 1885 (1890) and 1900, 6) the average household size between 1885 (1890) and 1900, 7) the share in manufacturing between 1882 and 1895 and 8) the share of movers between 1885 (1890) and 1900. Robust standard errors are reported in parentheses. ***, **, and * denote significance at 10%, 5%, and 1%, respectively.

The regressions using day laborer wages as the dependent variable in Columns 5 to 8 in Table 2 also show a stable positive association between expenditures per student and day laborer wages even though the coefficient on educational expenditures is substantially lower than the one for income tax per capita.[15] Just as in the estimations investigating income tax per capita, the association reduces by almost half once the possibly endogenous covariates are

[15] As the variable of interest and the covariates in the estimations on income tax per capita stem from 1885 and 1886 and those on day laborer wages of 1890 and 1891, the coefficients are not directly comparable.

included in Column 7. In the preferred specification in Column 6 an increase in educational expenditures per student by 10 percent is correlated with a 3.4 percent increase in day laborer wages.

5.2 A value-added approach

The identification of the value-added approach is based on the assumption that the lagged value of the outcome variable absorbs all sources of endogeneity (Todd and Wolpin, 2003), i.e. any potential correlation between the variable on educational investments and the error term is eliminated when controlling for the lagged value of the outcome variable. While controlling for the lagged value of the outcome variable, historical endowments and inputs affecting economic development are accounted for. However, there might be contemporary shocks that influence both income or day laborer wages and educational expenditures simultaneously. Counties that highly invest in primary education might also invest in other types of public goods, especially in other sectors of education, such as secondary or tertiary education, that equally affect economic development. At the time of observation, publicly funded universities established research and development departments contributing to innovations which eventually translated into higher income. If investments in primary education and other investments in public goods, enhancing economic development, are correlated, the estimates would overestimate the true effect of investments in primary education.

Measuring outcomes 15, respectively ten years, after inputs are measured, bears the danger of structural changes affecting economic development in the intervening years. Assuming that these structural changes positively affect economic development and are positively correlated with educational investments, the estimates might again be overestimated. In order to evade this bias, the absence of additional input factors has to be assumed.

The student cohorts of 1886 and 1891 only constitute roughly 20 percent of the labor force once students enter the labor market. This, at the other hand, would mean that the estimate has to be interpreted as a lower bound of the true effect.

Further bias might arise when using the income tax data. As the Prussian minister of finance Johann von Miquel introduced a major tax reform in 1891, changing the income tax system from a class tax to a tax system with progressive elements, the reform would have to affect all Prussian counties in the same way to avoid any bias. Figure 4 illustrates the changes in tax rates following from the reform showing that people at the very high end of the income distribution had to pay proportionally more taxes after 1891. If counties with a relatively high share of the population at the top of the income distribution invest more in primary education, this might again lead to overestimating the true effect of primary educational investments as increases in the income tax generated through the reform would be attributed to higher educational investments.

Another drawback of the income tax data is that income taxes are censored at a minimum of 900 Marks which prevents observing increases in income at the low end of the income distribution. If income in a county increases on average, but people remain below the threshold of 900 Marks, the estimate would have to be considered as a lower bound estimate on the effect on the upper part of the income distribution. Otherwise, I have to assume that any substantial increase in income is only made once the threshold of 900 Marks is exceeded. Using day laborer wages allows shedding some light on the effect on the lower part of the income distribution.

Another flaw of the income tax measure is possible tax evasion. Income taxes were paid according to the self-reported income of each household (Hill, 1892).[16] If tax evasion differed

[16] Hill (1892) reports that incomes were reported at less than one half or even less than one third of their true value with huge variations in this miss-reporting.

across counties and was high in counties with low educational investments, the estimate would again be an upper bound of the true effect.

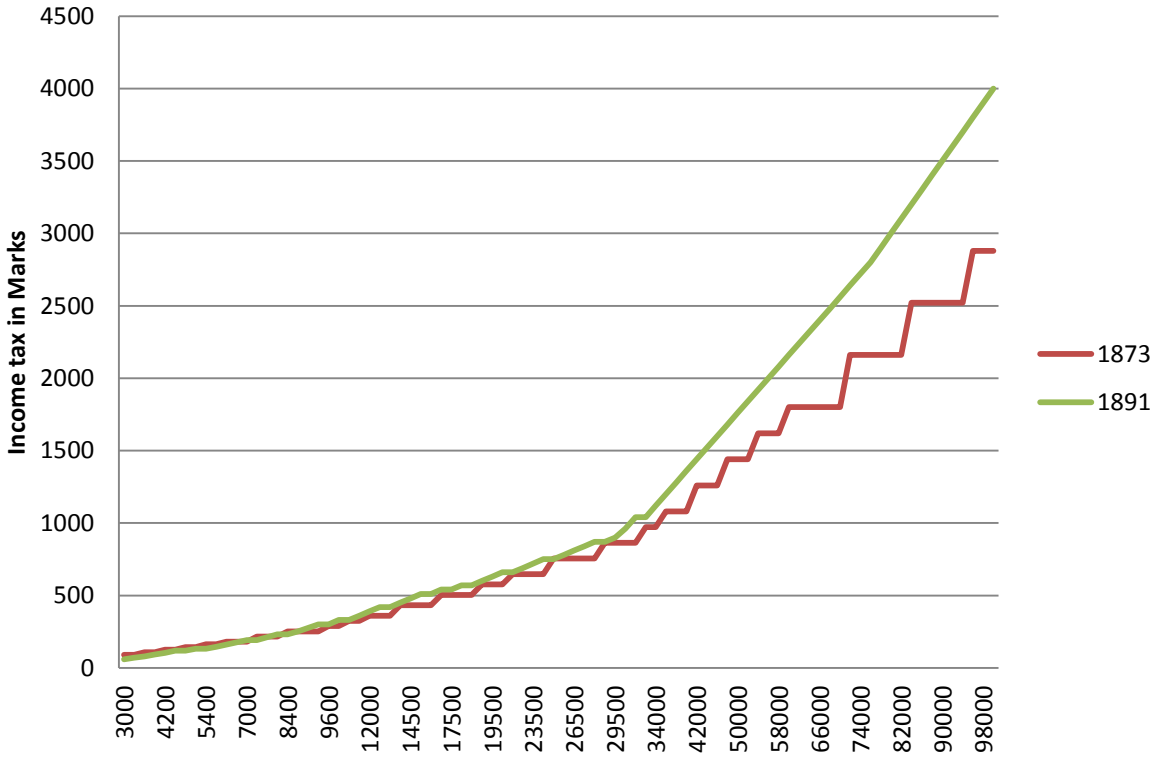
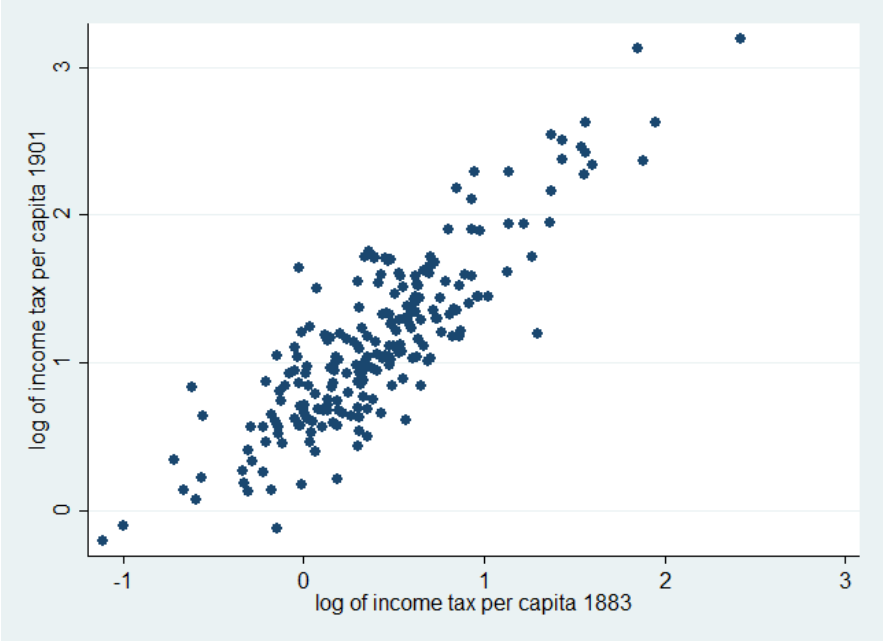


Fig. 4. Income tax per capita—changes between 1873 and 1891
Note: Income classes depicted for 1873. Progressive income tax depicted for 1891. Source: Own illustration following Hill (1892).

However, given the data available, the VA approach is the best available method reducing biases arising from both omitted variables and reversed causality. To the best of my knowledge, this is the first study that applies this approach in a historical context, allowing better identifying a causal relationship between educational inputs and outcomes. Assuming the absence of any other simultaneous shifts that might impact economic development, the VA approach is able to reduce the concern of reversed causality and accounts for some bias evolving from omitted variables. If following the standard view in the literature that both educational investments and economic progress are cumulative processes, the VA approach will account for the likely correlation between locally funded educational investments and income tax per capita by controlling for the lagged outcome variable.

Figure 5 illustrates the predictive power of income tax per capita in 1883/84 for income tax per capita in 1901 and equally of day laborer wages in 1892 for day laborer wages in 1901. The correlation coefficient between income tax per capita in 1883/84 and 1901 is 0.87 and 0.93 for day laborer wages illustrating the strength of the approach.

Income tax per capita in 1883/84 and 1901



Day laborer wages for men over 16 years in 1892 and 1901

Fig. 5. Predictive power of income tax per capita in 1883 and 1901 and day laborer wages in 1892 and 1901
Note: The correlation coefficient between log of income tax per capita in 1883/84 and in 1901 is 0.87. The correlation coefficient between log of day laborer wages in 1892 and 1901 is 0.93. Source: See Appendix for data sources.

The estimation equation for the VA specification looks as follows:

$$logY_{i,t} = \alpha + \beta\, e_{i,t} + X'_{i,t}\gamma + logY_{i,t-1} + \alpha_p + \varepsilon_i \quad (2)$$

where $logY_{i,t-1}$ indicates the lagged outcome variable, i.e. income tax per capita in 1883/84 or day laborer wages in 1892 respectively, while the other parts of the estimation specification concur with the OLS specification.

The lagged outcome variable for the estimation using income tax per capita is measured in 1883/84, i.e. prior to the educational inputs of 1886. I thereby assume that any kind of income shock that might have occurred between 1883/84 and 1886 is not systematically related to the amount of educational inputs invested in 1886.

5.3 Results of value-added approach

The results of the value-added approach are presented in Table 3. Once I control for the initial levels of development by including the lagged outcome variable for income tax per capita (Table 3, Columns 1 to 4), the coefficient on overall expenditures per student decreases by at least half, but remains significant in all specifications, ranging between 0.665 and 0.304, i.e. increasing overall expenditures per student by 10 percent raises income tax per capita in 1901 by about 6 percent in the preferred specification in Column 2, i.e. the coefficient from the OLS regression is reduced by a factor of three. Bearing in mind the rather low and often statistically insignificant estimates from the literature on contemporary educational production functions (Hanushek, 1997), these findings are worth noting. They stress that educational policy through investments in education contributed to meet the increased demand of human capital through the industrial progress evoked by the Second Industrial Revolution and allowed for technological progress complementing the study of Becker, Hornung and Woessmann (2011).

The VA coefficient remains high and strongly significant throughout all specifications, supporting the power of the approach in capturing underlying differences.[17] Furthermore, the explained variance of the model exceeds 80 percent in the preferred specification, indicating the high explanatory power of the regression model.

When looking at day laborer wages in Columns 5 to 8 in Table 3, the significant positive correlation between day laborer wages and expenditures per student found for the conditional correlations in Table 2 disappears as soon as initial wage levels are considered. As discussed

Table 3

Economic development and spending on education: Value-Added (VA) estimates

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dep. Var.:	Income tax per capita 1901 (log)				Day laborer wages 1901 (log)			
Expenditures p.	0.665***	0.583***	0.307**	0.304**	-0.029	0.030	-0.018	-0.021
stud. (log)	(0.101)	(0.102)	(0.119)	(0.118)	(0.035)	(0.032)	(0.038)	(0.036)
VA term	0.779***	0.843***	0.722***	0.713***	0.905***	0.855***	0.726***	0.705***
	(0.048)	(0.053)	(0.060)	(0.053)	(0.048)	(0.051)	(0.053)	(0.053)
Protestant		0.059	-0.020	-0.076		-0.011	-0.020	-0.020
		(0.080)	(0.063)	(0.055)		(0.025)	(0.023)	(0.024)
Female		-3.410**	-3.459**	-3.022**		-0.004	0.266	0.123
		(1.697)	(1.536)	(1.449)		(0.469)	(0.481)	(0.472)
Landownership		-17.954	-4.450	-6.599		-2.790	-2.658	-2.340
concentration		(11.510)	(7.205)	(4.444)		(2.518)	(3.014)	(2.452)
Exogenous GR	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Province FE	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Add. Controls	No	No	Yes	Yes	No	No	Yes	Yes
Endogenous GR	No	No	No	Yes	No	No	No	Yes
Observations	217	217	217	217	217	217	217	217
R-squared	0.79	0.83	0.89	0.91	0.84	0.86	0.89	0.91

Note: Value-Added estimates. The dependent variable is the logarithm of income tax per capita in 1901 in Columns 1 to 4 (and the logarithm of the average male day laborer wages over 16 years in 1901 in Columns 5 to 8). The variable of interest, expenditures p. stud. (log) is the log of total expenditures per student in 1886. The VA term is the logarithm of income tax per capita in 1883/84 in Columns 1 to 4 (and the logarithm of the average male day laborer wages over 16 years in 1892 in Columns 5 to 8). Protestant denotes the share of Protestants in 1885 (1890). Female denotes the share of females in 1885 (1890). Landownership concentration denotes the share of farms larger than 100 ha arable land in 1882. Exogenous GR include the growth rates of 1) the Protestant share between 1885 (1890) and 1900, 2) the female share between 1885 (1890) and 1900, (3) landownership concentration between 1882 and 1895. Province-fixed effects are for six provinces. Additional Controls include urbanization, average household size, employed in manufacturing, movers and municipal contributions for the estimations on log income tax per capita. Endogenous GR include the growth rates of 4) the share of people living in cities between 1885 (1890) and 1900, 5) the population between 1885 (1890) and 1900, 6) the average household size between 1885 (1890) and 1900, 7) the share in manufacturing between 1882 and 1895, and 8) the share of movers between 1885 (1890) and 1900. Robust standard errors are reported in parentheses. ***, **, and * denote significance at 10%, 5%, and 1%, respectively.

[17] The VA coefficient decreases remarkably once the endogenous covariates are included in column 3 as those variables could themselves be outcomes of the educational production function.

in section 5.2 this could be due to an underestimation of the effect as only a small share of students of 1891 constituted the labor force of 1901. However, the coefficient might also be an upper bound due to a classical omitted variable bias where investments in primary education could be correlated with unobserved other investments. The coefficient turns negative once including the endogenous controls in Columns 7 and 8, though it is not significant at a statistical level. As in the regressions on income tax per capita, the VA term is high and strongly statistically significant and the explanatory power of the regression model is high.

As day laborer wages are reported both for rural and urban municipalities and the education census also distinguishes between rural and urban parts of a county, it is possible to run regressions for day laborer wages at a more disaggregate level. The covariates included are only available at the aggregate county level and will be included as such.

Table 4 reports the results on the rural and urban sample of day laborer wages. The OLS estimate for the full sample, reported in Column 1 (Table 4), is slightly lower than the aggregate county estimate in Column 6 of Table 2.[18] The correlation between expenditures per student and day laborer wages is slightly higher in the disaggregated urban and rural sample, displayed in Columns (2) and (3). However, once the VA term is introduced in Columns 4 to 6, the coefficient turns negative for all samples. The coefficient is statistically significant at the 10 percent significance level in the rural sample. At the disaggregate level, day laborer wages might even decrease in counties with high educational expenditures.

[18] Note that I lose 14 observations in the urban sample and 15 observations in the rural sample as there are 14 counties being entirely rural and 15 counties being entirely urban.

Table 4

Day laborer wages and spending on education in the rural and urban sample: OLS and VA estimates

Dep. Var.: Day laborer wages of respective sample	(1) Full	(2) OLS Urban	(3) Rural	(4) Full	(5) Value-Added Urban	(6) Rural
Expenditures per student (log)	0.313***	0.352***	0.347***	-0.010	-0.032	-0.082*
	(0.062)	(0.090)	(0.120)	(0.017)	(0.027)	(0.044)
VA term				0.953***	0.954***	0.960***
				(0.013)	(0.017)	(0.023)
Protestant	-0.100*	-0.102	-0.099	-0.011	-0.012	0.001
	(0.056)	(0.091)	(0.069)	(0.018)	(0.022)	(0.029)
Female	-9.034***	-8.984***	-8.854***	0.088	0.035	-0.032
	(1.397)	(2.116)	(1.656)	(0.335)	(0.454)	(0.515)
Landownership concentration	-19.667**	-14.933	-32.489***	-2.177	-0.864	-3.708
	(8.396)	(9.318)	(9.217)	(1.870)	(1.897)	(3.581)
Exogenous GR	Yes	Yes	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	405	203	202	405	203	202
R-squared	0.44	0.38	0.53	0.95	0.96	0.95

Note: OLS and Value-Added estimates. The dependent variable is the logarithm of male day laborer wages over 16 years in 1901. The variable of interest, expenditures per student (log) is the log of total expenditures per student in 1886. The VA term is the logarithm of male day laborer wages over 16 years. All covariates are measured at the aggregate county level. Protestant denotes the share of Protestants in 1890. Female denotes the share of females in 1890. Landownership concentration denotes the share of farms larger than 100 ha arable land in 1882. Urbanization is the share of people living in cities in 1890. Average household size is the average number of people living in private households in 1890. Employed in manufacturing denotes the percentage of workers employed in manufacturing in 1882. Movers denote the share of people born in another locality than their resident locality in 1890. Exogenous GR include the growth rates of 1) the Protestant share between 1890 and 1900, 2) the female share between 1890 and 1900, 3) landownership concentration between 1882 and 1895. Province-fixed effects are for six provinces. Robust standard errors are reported in parentheses. ***, **, and * denote significance at 10%, 5%, and 1%, respectively.

However, as substantial movement from the countryside to the cities was going on at the time with people searching for better employment opportunities in the nearby cities, [19] the county-level is considered as the more appropriate aggregation level capturing students who moved to the cities, found higher-paid jobs and thereby might have increased their wages.[20]

Consolidating the evidence on income tax per capita and day laborer wages, it seems that investing in education increased earnings at the high end of the income distribution, while earnings at the low end of the income distribution are unaffected. Higher educational expenditures were embodied in the population allowing people to leave the low income segment where they were exempted from paying income tax and consequently shifted to higher skilled

[19] Note that the share of the population that had moved within a county averaged at 15 percent in 1891.

[20] The wage premium of urban day laborers as compared to rural day laborers amounted to 10 percent of urban day laborer wages.

jobs, surpassing the annual relief threshold of 900 Marks and consequently becoming liable to pay income taxes. As there was an ample supply of labor—with the share of people without employment amounting to 8 percent in 1895[21]—unskilled laborers could be easily substituted. With the supply of low skilled laborers exceeding the demand, day laborer wages remained flat.

As Prussia experienced the second phase of the Industrial Revolution which was characterized by the introduction of new industrial technologies leading to an increased demand for human capital (Galor and Moav, 2006), this finding goes very much in line with the historical circumstances and provides evidence for the hypothesis that educational policy contributed to meeting the increased demand of human capital evoked by the Second Industrial Revolution and allowed for technological progress through investments in education which complements the findings by Becker, Hornung and Woessmann (2011).

Following this interpretation possibly reduces the bias evolving from the fact that the student cohorts of 1886 and 1891 only make up roughly 20 percent of the labor force in 1901. If there are such general equilibrium effects that the students of 1886 take higher skilled jobs, but older, less qualified workers remain in their positions, being complements to the young higher skilled work force, the concern of underestimating the true effect is much less reasonable. As most of the other biases described in section 5.2 point at overestimating the true effect, it is very likely, that an upper bound of the true effect is estimated, especially for the models using income tax per capita as the dependent variable.

[21] Even though, an unemployment rate of 8 percent is not high by definition, the official rate might be underreported and the historical literature reports that especially low-skilled laborers faced high competition in the labor market, especially as people migrated from the rural areas to the cities and from the agricultural East to the industrializing West (Kochendörfer, 1997).

5.4 Decomposing educational expenditures

Following the literature on educational production functions, I decompose educational investments into three components in order to capture the teacher-student ratio, teacher unit costs, and investments in infrastructure.

Estimates from OLS and VA models, displayed in Columns 1 to 4 for income tax per capita and Columns 5 to 8 for day laborer wages (Table 5), point into the same direction. As OLS results might be biased for the reasons discussed above, the discussion focuses on the VA estimates.

In the preferred model for income tax per capita in Column 4, a higher provision of teachers significantly reduces income tax per capita, whereas teacher unit costs and infrastructure expenditures per student both increase income tax per capita. The coefficient on the number of teachers per student is only significant at the 10 percent level. The negative association might be surprising at first. However, the consensus in the modern literature on educational production functions is that class size does not matter for student performance. The result is still remarkable given the huge class sizes at the time where one teacher would be in charge of at the least 50 up to 125 students. Angrist and Lavy's (1999) well identified study examining large reductions in class size by exploiting the Maimonides' Rule mandating that class size should not exceed 40 students finds increases in test scores for fourth and fifth graders, though not for third graders. One possible explanation for the finding in the Prussian setting is that class size does not matter once exceeding a certain threshold as it e.g. demands particular lecturing styles. As multi-grade classes were still prevalent in the rural parts of late nineteenth-century Prussia, teachers mostly assigned exercises of different levels which students would solve in silent work. When teachers taught new contents, this was done in teacher-up-front style not allowing for individual support for students that lacked behind their peers (Geissler, 2011).

Table 5

Decomposing spending on education: OLS and VA estimates

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dep. Var.:	Income tax per capita 1901 (log)				Day laborer wages 1901 (log)			
	OLS		VA		OLS		VA	
Teacher-student ratio	-0.021	-0.019	-0.151**	-0.147*	-0.082*	-0.083*	-0.072**	-0.023
	(0.133)	(0.142)	(0.073)	(0.083)	(0.047)	(0.049)	(0.032)	(0.034)
Teacher unit costs (log)	2.195***	2.482***	0.938***	0.990***	0.417***	0.464***	0.173***	0.154**
	(0.211)	(0.273)	(0.154)	(0.182)	(0.072)	(0.091)	(0.048)	(0.063)
Infrastructure exp. (log)	0.482***	0.428***	0.265***	0.233***	0.170***	0.158***	0.015	0.005
	(0.074)	(0.080)	(0.052)	(0.055)	(0.026)	(0.023)	(0.020)	(0.020)
VA term			0.729***	0.737***			0.803***	0.820***
			(0.054)	(0.054)			(0.053)	(0.053)
Protestant	-0.015	-0.163*	-0.080	-0.037	-0.060**	-0.040	-0.044***	-0.029
	(0.069)	(0.093)	(0.051)	(0.071)	(0.029)	(0.040)	(0.017)	(0.026)
Female	-1.263	-1.882	-2.464*	-3.263**	-2.390***	-2.213***	-0.089	-0.022
	(1.894)	(2.376)	(1.362)	(1.564)	(0.675)	(0.711)	(0.446)	(0.455)
Landownership concentration	18.130**	12.154	-9.523	-8.882	-7.972	-4.603	-2.181	-2.066
	(7.650)	(9.304)	(8.737)	(9.643)	(5.506)	(5.486)	(2.437)	(2.712)
Exogenous GR	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province FE	No	Yes	No	Yes	No	Yes	No	Yes
Observations	217	217	217	217	217	217	217	217
R-squared	0.38	0.43	0.85	0.86	0.50	0.52	0.79	0.81

Note: OLS and VA estimates. The dependent variable is the logarithm of income tax per capita in 1901 in Columns 1 to 4 (and the logarithm of the average male day laborer wages over 16 years in 1901 in Columns 5 to 8). The variables of interest are the teacher-student ratio in 1886 (1891), i.e. the number of teachers per 100 students, teacher unit costs (log) in 1886 (1891) which denote the average spending per teacher, and infrastructure exp. (log) in 1886 (1891) which comprise the expenditures for the construction, enlargement and maintenance of school buildings per student. Protestant denotes the share of Protestants in 1885 (1890). Female denotes the share of females in 1885 (1890). Landownership concentration denotes the share of farms larger than 100 ha arable land in 1882. Exogenous GR include the growth rates of 1) the Protestant share between 1885 (1890) and 1900, 2) the female share between 1885 (1890) and 1900, 3) landownership concentration between 1882 and 1895. Province-fixed effects are for six provinces. Robust standard errors are reported in parentheses. ***, **, and * denote significance at 10%, 5%, and 1%, respectively.

Higher teacher wages are one to one translated into higher income tax per capita. Increasing infrastructure expenditures per student by 10 percent translates into an increase of income tax per capita of 2 percent.

The VA estimates on day laborer wages, depicted in Columns 7 and 8, point in the same direction as the estimates for income tax per capita. However, only the coefficient on teacher unit costs is significant at the 5 percent level in the preferred specification, displayed in Column 8. Even though, no significant association is found for the overall investments in education and day laborer wages as shown in Table 3, teacher salary—and therefore the quality of teachers—seems to be positively correlated with day laborer wages.

The results, both for income tax per capita and day laborer wages thereby confirm the findings of the contemporary educational production functions for the historical context of Prussia in the ending nineteenth century: It is teacher quality that matters for economic development.

5.5 Sectoral shifts

Having hypothesized that the increase of income tax per capita through higher educational expenditures and the simultaneous flat response of day laborer wages stem from the fact that people educated in 1886 managed to enter higher paid and higher skilled jobs might be supported by the fact that counties benefitting from higher educational expenditures managed to translate these expenditures into shifting away from agriculture to "modern" sectors of the economy.

Data from the occupation censuses in 1882 and 1895 allow applying a VA approach observing shifts of the six main occupational sectors, defined by the Royal Statistical Office of Prussia. The Statistical Office distinguishes between the sectors for agriculture, manufacturing, service, domestic services, military and workers without occupation. More than 40 percent of workers were still employed in the agricultural sector, followed by roughly one third working in manufacturing in 1882 and 1895. The remaining work force was constituted of workers in services, domestic services, the military and those without occupation. If my hypothesis was correct, workers should shift from the agricultural sector where wages were rather flat and relatively low to the manufacturing or service sector[22] where skills such as reading, writing and calculus were required. The manufacturing sector needed skilled workers who were able to apply newly introduced technology such as new production machines. The Second Industrial Revolution in Prussia meant in particular the rise of the chemical and optical industry as well as of electrical and mechanical engineering. These new industries were

[22] The service sector comprises trade business, insurance, transport, lodging, and restaurants.

based on connecting research and industrial production. Beyond general skills in reading, writing and calculus, chemical and physical knowledge was therefore required (Hahn, 2005). Even though primary school might have not conveyed this specific knowledge, it might have contributed to the screening process of finding those candidates being able to acquire and apply this knowledge (Landes, 1994). With the growing importance of formal skills, skills acquired on the job lost importance (Lente and Altena, 2009).

Beyond screening able students, primary education might have mediated the direct productive use of skills such as reading, writing and calculus which were important to understand written instructions. Furthermore, behavioral traits and non-cognitive skills taught in primary school such as discipline and obedience could have been important for workers to get along in a working environment that was marked by the time device of machines (e.g. Bowles, Gintis and Osborne 2001). As work became increasingly technical, primary school might have also contributed to the ability to adapt new technologies (Nelson and Phelps, 1966). The mechanization of work also led to a segmentation of the labor market. Ancillary jobs in different trades required supervisory personnel. This technically qualified supervisory personnel received income at the high end of the income distribution while unqualified ancillary workers received income at the low end of the income distribution. Furthermore, skills acquired in primary school might have fed the newly emerging sector of white collar workers, especially requiring reading, writing and calculating skills, required mostly in the service sector.

I expect the manufacturing and the service sector to increase as I expect these two sectors to require skills acquired in primary school. As a by-product of a society with on average higher income thanks to higher educational expenditures, I equally expect the domestic service sector to increase as demand for domestic services will increase with more workers entering the high-wage segment of the economy. I expect the agricultural sector to decrease as a consequence of workers shifting to the "modern" sectors, namely manufacturing and services.

If new employment opportunities are generated with higher educational expenditures, e.g. in the domestic service sector, the share of workers without occupation might decrease. The share of workers employed in the military is expected to be unaffected.[23]

As the error terms of the estimations on each sector are very likely to be correlated, I use seemingly unrelated regressions to estimate the coefficients of each sector.

Table 6 (Panel A) shows how investments in primary education affected the sectoral composition of the economy. As expected, higher expenditures in primary education correlate positively with an increase in manufacturing (Column 2), service (Column 3) and domestic services (Column 4). It is the manufacturing sector that benefits most from investments in education. The higher wage receiving population (in the manufacturing and service sector) seems to react by increasing the demand for domestic service personnel which is reflected by the positive coefficient on domestic services. The increase in those sectors goes along with a decrease in the agricultural sector (Column 1) and a decrease in people without any occupation (Column 6). However, only the coefficient on agriculture is statistically significant. The coefficient on the military share is positive, but very small and also insignificant (Column 5).

When decomposing educational investments into the components teacher-student ratio, teacher unit costs and infrastructure expenditures per student (Table 6, Panel B), the teacher-student ratio and the share of workers employed in agriculture are positively correlated (Column 1). For all other sectors, I observe a negative interplay between the teacher-student ratio and the share employed in the respective sector which is significant for the share employed in manufacturing only (Column 2).

[23] Even though the original aim of Prussian school was to education a strong military, the size of the military sector is expected to react to other factors besides educational investments.

Table 6

Sectoral shifts and spending on education: VA estimates for West Elbia

Dep. Var.: Share in	(1) Agriculture	(2) Manufacturing	(3) Service	(4) Domestic Services	(5) Military	(6) Without occupation
PANEL A: Expenditures per student (log)						
Expenditures per student (log)	-0.065***	0.051***	0.036***	0.008***	0.004	-0.009
	(0.022)	(0.012)	(0.006)	(0.003)	(0.006)	(0.006)
VA term	0.877***	0.917***	0.933***	0.283***	0.978***	0.930***
	(0.019)	(0.018)	(0.032)	(0.022)	(0.028)	(0.041)
R-squared	0.89	0.93	0.84	0.57	0.82	0.67
PANEL B: Decomposition						
Teacher-student ratio	0.114***	-0.084***	-0.006	-0.004	-0.001	-0.002
	(0.026)	(0.016)	(0.006)	(0.003)	(0.007)	(0.008)
Teacher unit costs (log)	-0.069	0.056**	0.054***	-0.002	0.011	-0.006
	(0.046)	(0.026)	(0.012)	(0.006)	(0.012)	(0.013)
Infrastructure exp. (log)	-0.060***	0.041***	0.013***	0.005***	0.001	-0.002
	(0.015)	(0.009)	(0.004)	(0.002)	(0.004)	(0.004)
VA term	0.834***	0.864***	0.884***	0.303***	0.947***	0.910***
	(0.020)	(0.018)	(0.032)	(0.022)	(0.027)	(0.040)
R-squared	0.90	0.94	0.86	0.57	0.83	0.67
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Exogenous GR	Yes	Yes	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	217	217	217	217	217	217
Mean dep. var. in						
1882	0.43	0.33	0.09	0.01	0.05	0.05
1895	0.42	0.36	0.07	0.08	0.04	0.08

Note: Value-Added estimates using seemingly unrelated regressions. The dependent variable is the share of workers employed in agriculture in 1895 in Column 1, the share of workers employed in manufacturing in 1895 in Column 2, the share of workers employed in service in 1895 in Column 3, the share of workers employed in domestic services in 1895 in Column 4, the share of workers employed in the military in 1895 in Column 5 and the share of people without any occupation in 1895 in Column 6. The variable of interest is the log of total expenditures per student in 1886 in PANEL A. The variables of interest are the teacher-student ratio in 1886, i.e. the number of teachers per 100 students, teacher unit costs (log) in 1886 which denote the average spending per teacher and infrastructure exp. (log) in 1886 which comprise the expenditures for the construction, enlargement and maintenance of school buildings per student in PANEL B. The Value-Added term is the share of workers employed in agriculture in 1882 in Column 1, the share of workers employed in manufacturing in 1882 in Column 2, the share of workers employed in service in 1882 in Column 3, the share of workers employed in domestic services in 1882 in Column 4, the share of workers employed in the military in 1882 in Column 5 and the share of people without any occupation in 1882 in Column 6. Protestant denotes the share of Protestants in 1885. Female denotes the share of females in 1885. Landownership concentration denotes the share of farms larger than 100 ha arable land in 1882. Exogenous GR include the growth rates of 1) the Protestant share between 1885 and 1900, 2) the female share between 1885 and 1900, 3) landownership concentration between 1882 and 1895. Province-fixed effects are for six provinces. Standard errors are reported in parentheses. ***, **, and * denote significance at 10%, 5%, and 1%, respectively.

The positive association between overall expenditures in primary education and the share of workers employed in manufacturing and services is mainly driven by higher teacher unit costs as shown in Columns 2 and 3. Infrastructure expenditures are positively correlated with the share of people employed in manufacturing, service and domestic services (Columns 2 to 4). Infrastructure expenditures are negatively correlated with the share of workers employed

in the agricultural sector. More money invested in expanding schools correlates with a smaller agricultural sector. Expanding school capacity might have offered students the necessary skills to move away from the agricultural sector and find employment in another sector. The VA term is fairly high for all sectors with the exception of domestic services both in Panel A and B.[24]

5.6 East Elbia as a counterfactual

As shown in Figure 3, income tax per capita east of the river Elbe remained rather low and did not show a lot of variation in 1901. As described above, the East of Prussia still heavily relied on the agricultural sector with the manufacturing sector only reaching 25 percent of workers employed in 1895 (as compared to one third in West Elbia). As hypothesized above, the increase in income tax per capita through higher educational investments worked through a sectoral shift of the economy. As this shift was not realized in the East of Prussia, no association between educational investments and income tax per capita is expected to be found for this part of Prussia. In order to stress this counterfactual argument, I will first show that higher educational expenditures initiated a much less pronounced sectoral shift to "modern" sectors east of the Elbe, applying the same data source and estimation specification as in section 5.5 for the sample east of the Elbe.

Table 7 shows results on the sectoral shifts in East Elbia. Even though an increase in the manufacturing and the service sector through higher educational expenditures can be observed (Panel A, Columns 2 and 3), the shift in the manufacturing sector is much less pronounced with the coefficient being half as high once compared to the coefficient in the West Elbian sample. The coefficient on the service sector draws near the coefficient for the sample west of the Elbe, but still stays below it. No significant association is found for the domestic service sector (Column 4). Even though slight shifts to the manufacturing and the service sectors can

[24] This is owed to the fact that the category of domestic servants is abolished after 1882 and combined with domestic services in this analysis.

be observed, the workers do not seem to shift to higher paying jobs to the extent that it allows them to occupy domestic workers and consequently increase the demand for workers in this sector. The coefficient on the agricultural sector (Column 1) is negative, though not significant. Educational investments east of the Elbe did not allow for a shift out of agriculture. The increases in the manufacturing and the service sector come mainly from unemployed people finding work as the negative coefficient in Column 6 shows.

Panel B of Table 7 depicts results on decomposing educational investments into the teacher-student ratio, teacher unit costs and infrastructure expenditures. As for the findings for the sample west of the Elbe, the increase in the manufacturing and the service sector are first of all driven through higher teacher unit costs and to a lower extent through higher investments in educational infrastructure (Columns 2 and 3). Higher teacher unit costs and investments in educational infrastructure equally drive people out of the agricultural sector (Column 1). The teacher-student ratio is positively associated with the share of workers employed in agriculture and the share of the work force without any occupation while it is negatively associated with the share of workers employed in manufacturing, domestic services and the military.[25]

Having seen that higher educational investments translated into comparatively minor shifts towards sectors which encompassed the modernizing and industrializing occupations of the time, I expect an attenuated increase in income. Estimating equation 2 for the sample east of the Elbe allows testing this hypothesis. Table 8 shows results on the association between educational investments and the two outcome variables for the sample east of the Elbe. As expected no association between expenditures per student and income tax per capita is found

[25] One possible explanation is that teacher supply is high in counties with no alternative employment opportunities where being a teacher promises relatively high wages and relatively high social status.

Table 7

Sectoral shifts and spending on education: VA estimates for East Elbia

Dep. Var.: Share in	(1) Agriculture	(2) Manufacturing	(3) Service	(4) Domestic Services	(5) Military	(6) Without occupation
			PANEL A: Expenditures per student (log)			
Expenditures per student (log)	-0.009	0.019*	0.027***	-0.003	0.002	-0.008*
	(0.015)	(0.010)	(0.005)	(0.005)	(0.009)	(0.004)
VA term	0.907***	0.915***	0.944***	0.522***	0.931***	0.896***
	(0.016)	(0.019)	(0.026)	(0.036)	(0.037)	(0.034)
R-squared	0.95	0.94	0.91	0.46	0.72	0.71
			PANEL B: Decomposition			
Teacher-student ratio	0.114***	-0.064***	-0.007	-0.021***	-0.026**	0.019***
	(0.017)	(0.014)	(0.005)	(0.005)	(0.011)	(0.005)
Teacher unit costs (log)	-0.099**	0.091***	0.055***	0.011	-0.015	-0.007
	(0.040)	(0.031)	(0.013)	(0.012)	(0.025)	(0.012)
Infrastructure exp.(log)	-0.049***	0.027***	0.013***	0.005	0.020***	-0.013***
	(0.010)	(0.008)	(0.003)	(0.003)	(0.007)	(0.003)
VA term	0.882***	0.885***	0.909***	0.523***	0.915***	0.867***
	(0.016)	(0.020)	(0.027)	(0.036)	(0.036)	(0.033)
R-squared	0.97	0.94	0.92	0.49	0.73	0.74
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Exogenous GR	Yes	Yes	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	235	235	235	235	235	235
Mean dep. var. in 1882	0.51	0.23	0.07	0.02	0.05	0.06
1895	0.50	0.25	0.06	0.10	0.04	0.10

Note: Value-Added estimates using seemingly unrelated regressions. The dependent variable is the share of workers employed in agriculture in 1895 in Column 1, the share of workers employed in manufacturing in 1895 in Column 2, the share of workers employed in service in 1895 in Column 3, the share of workers employed in domestic services in 1895 in Column 4, the share of workers employed in the military in 1895 in Column 5 and the share of people without any occupation in 1895 in Column 6. The variable of interest is the log of total expenditures per student in 1886 in PANEL A. The variables of interest are the teacher-student ratio in 1886, i.e. the number of teachers per 100 students, teacher unit costs (log) in 1886 which denote the average spending per teacher and infrastructure exp. (log) in 1886 which comprise the expenditures for the construction, enlargement and maintenance of school buildings per student in PANEL B. The Value-Added term is the share of workers employed in agriculture in 1882 in Column 1, the share of workers employed in manufacturing in 1882 in Column 2, the share of workers employed in service in 1882 in Column 3, the share of workers employed in domestic services in 1882 in Column 4, the share of workers employed in the military in 1882 in Column 5 and the share of people without any occupation in 1882 in Column 6. Protestant denotes the share of Protestants in 1885. Female denotes the share of females in 1885. Landownership concentration denotes the share of farms larger than 100 ha arable land in 1882. Exogenous GR include the growth rates of 1) the Protestant share between 1885 and 1900, 2) the female share between 1885 and 1900, 3) landownership concentration between 1882 and 1895. Province-fixed effects are for six provinces. Standard errors are reported in parentheses. ***, **, and * denote significance at 10%, 5%, and 1%, respectively.

(as shown in Panel A, columns 1 to 4).[26] However, day laborer wages are positively associated with higher investments in primary education (compare Panel A, columns 5 to 8) which is driven by higher teacher wages (depicted in Panel B). So, I in deed find human capital effects

[26] Decomposing educational investments into the three different inputs again shows a negative association between the teacher-student ratio and income tax per capita and a positive association for infrastructure expenditures in the preferred specification of Column 4.

for entire Prussia. While these effects allowed for a shift of workers to the high-skilled sector in Prussia west of the Elbe, these effects show up in a productivity increase of day laborers east of the Elbe.

Table 8

Economic development and spending on education east of the Elbe: VA estimates

Dep. Var.:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Income tax per capita 1901 (log)				Day laborer wages 1901 (log)			
PANEL A: Expenditures per student (log)								
Exp. p. stud.	-0.106	0.132	0.012	0.018	0.089**	0.120***	0.084**	0.078**
	(0.118)	(0.141)	(0.185)	(0.184)	(0.038)	(0.037)	(0.040)	(0.039)
VA term	0.799***	0.713***	0.513***	0.414***	0.743***	0.700***	0.567***	0.529***
	(0.048)	(0.051)	(0.057)	(0.049)	(0.039)	(0.041)	(0.052)	(0.052)
R^2	0.73	0.80	0.83	0.86	0.83	0.86	0.87	0.88
PANEL B: Decomposition								
Teach-er/stud.	-0.407***	-0.476***	-0.408***	-0.318**	0.014	0.028	0.037	0.065
	(0.095)	(0.122)	(0.120)	(0.127)	(0.027)	(0.040)	(0.044)	(0.046)
Teacher costs	1.019***	0.478	0.008	0.076	0.121***	0.146**	0.155**	0.215***
	(0.255)	(0.360)	(0.342)	(0.328)	(0.044)	(0.070)	(0.063)	(0.070)
Infras-tructure	0.065	0.273***	0.238**	0.150	0.039	0.049	0.017	-0.015
	(0.086)	(0.097)	(0.117)	(0.128)	(0.024)	(0.033)	(0.031)	(0.031)
VA term	0.671***	0.678***	0.505***	0.431***	0.747***	0.696***	0.564***	0.525***
	(0.057)	(0.055)	(0.058)	(0.052)	(0.039)	(0.043)	(0.053)	(0.052)
R^2	0.77	0.83	0.85	0.87	0.84	0.86	0.87	0.88
Controls	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Exo. GR	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Province	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Add. Controls	No	No	Yes	Yes	No	No	Yes	Yes
End. GR	No	No	No	Yes	No	No	No	Yes
Obs.	236	235	235	235	236	235	235	235

Note: Value-Added estimates. The dependent variable is the logarithm of income tax per capita in 1901 in Columns 1 to 4 (and the logarithm of the average male day laborer wages over 16 years in 1901 in Columns 5 to 8). The variable of interest (exp. p. stud.) is the log of total expenditures per student in 1886 in PANEL A. The variables of interest are the teacher-student ratio in 1886, i.e. the number of teachers per 100 students (Teacher/stud.), teacher unit costs (log) in 1886 which denote the average spending per teacher (teacher costs) and infrastructure expenditures (log) which comprise the expenditures for construction, enlargement and maintenance of school building per student (infrastructure) in PANEL B. The VA term is the logarithm of income tax per capita in 1883/84 in Columns 1 to 4 (and the logarithm of the average male day laborer wages over 16 years in 1892 in Columns 5 to 8). Protestant denotes the share of Protestants in 1885 (1890). Female denotes the share of females in 1885 (1890). Landownership concentration denotes the share of farms larger than 100 ha arable land in 1882. Exo. GR include the growth rates of 1) the Protestant share between 1885 (1890) and 1900, 2) the female share between 1885 (1890) and 1900, 3) landownership concentration between 1882 and 1895. Province-fixed effects are for six provinces. Additional Controls include urbanization, average household size, employed in manufacturing, movers and municipal contributions for the estimations on log income tax per capita. End. GR include the growth rates of 4) the share of people living in cities between 1885 (1890) and 1900, 5) the population between 1885 (1890) and 1900, 6) the average household size between 1885 (1890) and 1900, 7) the share in manufacturing between 1882 and 1895, and 8) the share of movers between 1885 (1890) and 1900. Robust standard errors are reported in parentheses. ***, **, and * denote significance at 10%, 5%, and 1%, respectively. Robust standard errors are reported in parentheses. ***, **, and * denote significance at 10%, 5%, and 1%, respectively.

6. Conclusion

This paper investigates the relationship of different educational inputs and educational outcomes in the historical context of late nineteenth-century Prussia, the pioneer in primary education, thereby combining the literature on modern educational production functions and the economic historical literature on the interplay of education and economic growth.

Rich county-level data from the Prussian education censuses of 1886 and 1891 are combined with data on income taxes in 1883/84 and 1901 and day laborer wages in 1892 and 1901. Income taxes and day laborer wages provide measures of long-term school performance for both the high and the low end of the income distribution.

As estimates from OLS models might be biased due to omitted variables such as the initial development level of a county, and reversed causality stemming from the fact that richer counties have more resources to invest in education, a value-added approach is applied. Hereby, the lagged outcome variable is included at the right-hand side of the estimation equation to capture past endowments of the county both in terms of school structures and economic development. Even though biases through contemporary shocks such as other public investments remain a concern, this approach is most suited to the data and reduces many biases evolving from OLS estimations.

By estimating different historical educational production functions for West Prussia in the ending nineteenth century, it is found that overall educational expenditures per student increased income tax per capita while day laborer wages remain unaffected. Educational investments increasing income at the high end of the income distribution primarily works through higher teacher wages proxying higher teacher quality as well as through infrastructure investments, though to a smaller extent. The teacher-student ratio affects both income tax per capita and day laborer wages negatively. As class size ranged between 50 and 125 students, other factors than the sheer provision of teachers seem to have mattered for educational out-

comes. As found in the literature investigating educational production functions in a contemporary setting, teacher quality seems to have been the most influential input.

A human capital effect on economic development is found for entire Prussia. While this effect translated into a shift to the high-skilled sector in the industrializing West of Prussia, the effect shows up in a productivity increase of day laborers in the East of Prussia which remained predominantly agricultural. Taken together, the findings support the hypothesis that educational investments contributed to meeting the increased demand of human capital which was brought about by the Second Industrial Revolution.

Appendix

Table A1: 1883/1886 – 1901 Variables

Income tax per capita 1901	Sum of income taxes over total population in 1901. (Königliches Statistisches Bureau in Berlin, 1905).
Income tax per capita 1883/84	Sum of income taxes over total population in 1883/84. (Königliches Statistisches Bureau in Berlin, 1884).
Employed in agriculture (share)	Share of workers employed in agriculture and animal husbandry (sector A) over working population in 1882 (Königliches Statistisches Bureau in Berlin, 1861–1934, vol. 76b).
Employed in manufacturing (share)	Share of workers employed in manufacturing (sector B) over working population in 1882 (Königliches Statistisches Bureau in Berlin, 1861–1934, vol. 76b).
Employed in service (share)	Share of workers employed in service (sector C) over working population in 1882 (Königliches Statistisches Bureau in Berlin, 1861–1934, vol. 76b).
Employed in domestic services (share)	Share of workers employed in domestic services and as domestic servants (sector D and G) over working population in 1882 (Königliches Statistisches Bureau in Berlin, 1861–1934, vol. 76b).
Employed in military (share)	Share of workers employed in public administration and military (sector E) over working population in 1882 (Königliches Statistisches Bureau in Berlin, 1861–1934, vol. 76b).
Without occupation (share)	Share of people without occupation (sector F) over working population in 1882 (Königliches Statistisches Bureau in Berlin, 1861–1934, vol. 76b).
Expenditures per student, incl. fringe benefits	Primary school expenditures, including fringe benefits, per student of mandatory school age (6-14) in 1886.
Teacher-student ratio	Ratio of fully employed teachers over 100 students attending public or private primary school in 1886.
Teacher unit costs	Total expenditures for personnel per fully employed teacher in 1886.
Infrastructure expenditures per student	Primary school expenditures allocated to infrastructure, i.e. construction, enlargement and maintenance of schools, per student of mandatory school age (6-14) in 1886.
Protestant (share)	Share of Protestants per total population in 1885 (Königliches Statistisches Bureau in Berlin, 1861-1934, vol. 96).
Female (share)	Share of females per total population in 1885 (Königliches Statistisches Bureau in Berlin, 1861-1934, vol. 96).
Landownership concentration	Share of farms larger than 100 ha arable land in 1882 (Königliches Statistisches Bureau in Berlin, 1861–1934, vol. 76c).
Urban (share)	Share of total population living in cities that held city rights in 1885 (Königliches Statistisches Bureau in Berlin, 1861-1934, vol. 89).
Average household size	Average number of people living in one private household in 1885 (Königliches Statistisches Bureau in Berlin, 1861-1934, vol. 96).
Movers (share)	Share of people born in another locality than their resident locality per total population in 1885 (Königliches Statistisches Bureau in Berlin, 1861-1934, vol. 96).
Municipal contr. (share)	Share of primary school expenditures, contributed by municipalities in 1886.

Note: Unless otherwise specified, the data stem from Königliches Statistisches Bureau in Berlin (1861–1934, vol. 101).

Table A2: 1892/1895 – 1901 Variables

Day laborer wages 1901	Average of urban and rural day laborer wages for men over 16 years in 1901 (Neuhaus, 1904).
Day laborer wages 1892	Average of urban and rural day laborer wages for men over 16 years in 1892 (Neuhaus, 1904).
Employed in agriculture (share)	Share of workers employed in agriculture and animal husbandry (sector A) over working population in 1895 (Kaiserliches Statistisches Reichsamt, 1872-1918, vol. 104 and 109).
Employed in manufacturing (share)	Share of workers employed in manufacturing (sector B) over working population in 1895 (Kaiserliches Statistisches Reichsamt, 1872-1918, vol. 104 and 109).
Employed in service (share)	Share of workers employed in service (sector C) over working population in 1895 (Kaiserliches Statistisches Reichsamt, 1872-1918, vol. 104 and 109).
Employed in domestic services (share)	Share of workers employed in domestic services (sector D) over working population in 1895 (Kaiserliches Statistisches Reichsamt, 1872-1918, vol. 104 and 109).
Employed in military (share)	Share of workers employed in public administration and military (sector E) over working population in 1895 (Kaiserliches Statistisches Reichsamt, 1872-1918, vol. 104 and 109).
Without occupation (share)	Share of people without occupation (sector F) over working population in 1895 (Kaiserliches Statistisches Reichsamt, 1872-1918, vol. 104 and 109).
Expenditures per student, incl. fringe benefits	Primary school expenditures, including fringe benefits, per student of mandatory school age (6-14) in 1891.
Teacher-student ratio	Ratio of fully employed teachers over 100 students attending public or private primary school in 1891.
Teacher unit costs	Total expenditures for personnel per fully employed teacher.
Infrastructure expenditures per student	Primary school expenditures allocated to infrastructure, i.e. construction, enlargement and maintenance of schools, per student of mandatory school age (6-14) in 1891.
Protestant (share)	Share of Protestants per total population in 1890 (Königliches Statistisches Bureau in Berlin, 1861-1934, vol. 121a).
Female (share)	Share of females per total population in 1890 (Königliches Statistisches Bureau in Berlin, 1861-1934, vol. 121a).
Landownership concentration	Share of farms larger than 100 ha arable land in 1882 (Königliches Statistisches Bureau in Berlin, 1861–1934, vol. 76c).
Urban (share)	Share of total population living in cities that held city rights in 1890 (Königliches Statistisches Bureau in Berlin, 1861-1934, vol. 117).
Average household size	Average number of people living in one private household in 1890 (Königliches Statistisches Bureau in Berlin, 1861-1934, vol. 121a).
Movers (share)	Share of people born in another locality than their resident locality per total population in 1890 (Königliches Statistisches Bureau in Berlin, 1861-1934, vol. 121a).

Note: Unless otherwise specified, the data stem from Königliches Statistisches Bureau in Berlin (1861–1934, vol. 120).

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