

# Modern Secondary Education and Economic Outcomes: The Introduction of the Gewerbeschule and Realschule in 19th Century Bavaria

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## **Abstract**

Do new school types focusing on practical and business-related knowledge lead to increased economic outcomes? To analyze this question, this paper examines the introduction of two types of modern secondary education, the Gewerbeschule and its successor, the Realschule, in 19<sup>th</sup> century Bavaria. Since opening of these schools is arguably endogenous – as it were mainly the prosperous, big cities that opened one – the estimated treatment effect capturing the economic influence of the Gewerbeschule/Realschule will lead to biased results. To alleviate this bias, I adopt propensity score matching to compare relatively alike counties with and without these schools and a differences-in-differences specification. Using historical county-level data on business formations, employment structure and patent holdings, OLS regression analysis shows that the opening of a modern secondary school is in most cases positively associated with economic growth several years later.

Keywords: economic development, education, history, pre-war Bavaria, school

JEL classification: I25, N33

# 1 Introduction

The importance of human capital for economic growth has been understood since the seminal works of Theodore Schultz (1961) and Gary Becker (1964) in the early 1960s. In this context, numerous empirical studies concerning the impact of schooling on economic growth have been conducted, e.g. Walters and Rubinson (1983), Behrman and Birdsall (1983), Fuller et al. (1986) and Liu and Armer (1993). However, research about the impact of different school types of 19th century Germany – and especially Bavaria – is practically non-existent.

In this paper, I examine the influence of modern secondary education in Bavaria, thereby focusing on the introduction of the Gewerbeschule<sup>1</sup> in 1829 and Realschule in 1877 and its impact on economic growth.

The Gewerbeschule was introduced in several Bavarian cities between 1829 and 1836 and paved the way for “modern secondary education”: in contrast to the (humanistic) Gymnasium – the predominant type of secondary schooling at that time – which focused mainly on classical languages and abstract teaching of mathematics, the curriculum of the Gewerbeschule contained a high proportion of so-called realistic subjects such as modern languages and natural sciences – skills that were (and still are) considered important contributors to economic growth. In 1877 the existing 40 Gewerbeschulen were replaced by Realschulen. By 1907 there were more than 50 Realschulen on Bavarian soil. The curriculum introduced an obligatory third language, a redefined focus on mathematics and natural sciences. Over the years, modern secondary education established itself as a popular alternative to traditional secondary education, i.e. (humanistic) Gymnasium. Rudolf Diesel – the inventor of the Diesel engine – is a prominent example of a modern secondary school career: growing up in Paris, he convinced his parents to send him to Augsburg to attend the local Gewerbeschule where his uncle was a teacher. Still at the Gewerbeschule (between 1870 and 1873) he decided to become an engineer. Therefore, he continued to the Industrieschule

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<sup>1</sup> Note that although Gewerbeschulen were called “Landwirtschaftsschule- und Gewerbeschulen” until 1864, in the following analyses I will use the term Gewerbeschule as an umbrella term for both schools.

and then to the Technische Hochschule Munich to study industrial engineering (Diesel, 1983, p. 57-59, 71, 83; Luther, 1987, p. 143ff.). Other prominent former students of modern secondary education are Heinrich von Buz, industrialist and manager of MAN (Gewerbeschule Augsburg, 1845-1849) (Luther, 1987, p. 133) and Friedrich Fischer, inventor, industrialist and founder of Kugelfabrik Fischer (Gewerbeschule Schweinfurt, ca. 1861-1866) (Mehr, 1987, p. 237ff.).

To assess the economic impact of modern secondary schooling, I employ county data on business formations, numbers of self-employed and employees in trade and industry. In case of the Realschule, I use the number of granted patents as an additional measure of economic performance. All variables capturing economic performance are measured several years after the opening of a Gewerbeschule/Realschule. As the introduction of modern secondary education in a city is correlated with the city's level of economic development, I employ two approaches: sample restriction via propensity scores and a differences-in-differences estimation.

I can show that modern secondary education indeed had a positive impact on economic performance. Counties that set up a Gewerbeschule by 1835 are significantly associated with more people employed in industry in 1882 and a higher number of net-business registrations than comparable counties without modern secondary schooling. Counties that later opened a Realschule presumably benefitted even more from modern secondary education: Having a Realschule is positively – albeit insignificantly – associated with more businesses and employees in industry and trade. However, there is a differential effect for early and late adopters: it seems as if only those counties that opened a Realschule relatively late profited the most.

This analysis contributes to the existing literature in several dimensions. In a broader context, it adds to the literature on the impact of schooling on economic growth. For example, Walters and Rubinson (1983) focus on the impact of educational expansion on economic output in the United States from 1890 to 1969. They find time-specific economic effects of secondary and doctorate education. Fuller et al. (1986) show for Mexico between 1888 and

1940 that school quality rather than quantity played an important role in economic growth. Becker et al. (2011) find that basic education played an important role in industrial catch-up to Britain in 19<sup>th</sup> century Prussia. Furthermore, this paper complements to the literature on the evaluation of the Bavarian schooling system during the 19<sup>th</sup> century. As there exist several narrative studies concerning the Prussian higher education system (for example Punke (1930a, 1930b), Ringer (1967, 1976) and Kraus (2008)), only Buchinger (1983) provides an in-depth analysis of modern secondary education in Bavaria. However, his analysis does not explore any economic effect of these schools. To the best of my knowledge, this paper provides the first econometric analysis of the impact of specific Bavarian school types, i.e. Gewerbeschule and Realschule, on economic outcomes.

The remainder of the paper is structured as follows: Chapter 2 provides an overview of the German educational system during the 19<sup>th</sup> and early 20<sup>th</sup> century. A special emphasis is thereby placed on the Bavarian schooling system. Moreover, it explores the channel through which the Gewerbeschule and Realschule might influence the economy. Chapter 3 introduces the empirical model and describes the data. Chapter 4 presents the results of the econometric approach. Chapter 5 concludes.

## **2 Historical Facts**

The following chapter provides an overview of the educational system in Germany during the 19<sup>th</sup> century. As the subsequent empirical approach analyses the impact of secondary schooling in Bavaria, a special emphasis is placed on the Bavarian educational system and in particular on the Gewerbeschule and Realschule.

### **2.1 Educational System in 19<sup>th</sup> Century Bavaria**

The most important form of German secondary schooling throughout the 19<sup>th</sup> century was the (humanistic) Gymnasium (Ringer, 1967, p. 128). Students transferred around age eleven after primary education – acquired either at a public school (“Volksschule”) or private institution (“Vorschule”) – first to the Lateinschule (Ringer, 1979, p. 33; Punke, 1930a, p. 576). Students were required to complete this four-year institution (after 1875: five-year) in order to be

entitled to attend the three-year Gymnasium (after 1833: four-year). Thus, after completion of the Gymnasium students were about 18 to 20 years old (depending on the respective decade). The curriculum of the Gymnasium focused on the classical languages Greek and Latin and abstract teaching of mathematics. Throughout the 19th century only the humanistic Gymnasium possessed the right to confer the Abitur – a prerequisite for university admittance (Ringer, 1979, p. 34; Kraus, 2008, p. 42).

The *Realschule* as a lower type of secondary education emerged during the 18th century in Prussia. Inspired by Hecker's "ökonomisch-mathematische Realschule" founded in Berlin in 1747, six-year Realschulen were opened all over Germany. The educational objective of the Realschule was to provide prevocational as well as general education, thereby focusing on mathematics, natural sciences and modern languages such as English and French (Hamann, 1993, p. 95ff.).

Especially in Bavaria, Realschulen were quite popular already at the beginning of the 19<sup>th</sup> century – although by no means as popular as the Gymnasium as the predominant type of secondary education. Between 1808 and 1816 there existed Realschulen focusing on technical education and preparing for transfer to Realinstitute which in turn entitled for university studies. A reorganization in 1816 transformed these early Realschulen into Höhere Bürgerschulen which combined general education and occupational training and Realinstitute were closed (Buchinger, 1983, p. 76ff.). These Höhere Bürgerschulen were then replaced by Gewerbeschulen.

The *Gewerbeschule* was officially introduced in 1829 by the Bavarian King Ludwig I, who commanded the opening of a Gewerbeschule in all big cities (Döllinger, 1838, p. 1691); in these cities, Bürgerschulen should be transformed into Gewerbeschulen (Buchinger, 1983, p. 127). Gewerbeschulen were designed as three-year schools and pupils directly transferred to them after having completed the Volksschule around age eleven (Buchinger, 1983, 122f.). A degree of the Gewerbeschule entitled to transfer to a Polytechnic School. This institution prepared for studies at the Technische Hochschule until they were replaced by Industrieschulen in 1868 (Buchinger, 1983, p. 123ff.). Since the original curriculum of 1833 mainly

provided a technical education, these early *Gewerbeschulen* can be understood as professional schools (Buchinger, 1983, p. 127f.). Furthermore, *Gewerbeschulen* had to include an agricultural department (Regierungsblatt, 1833, p. 183f.); thus they were called *Landwirtschafts- und Gewerbeschulen*. Table 1 illustrates the official curriculum for students of the *Gewerbeschule*. Besides the courses in Table 1, students had to visit the so-called *Realienunterricht* at a (humanistic) *Gymnasium* as depicted by Table 2.

**Table 1 - Curriculum *Gewerbeschule* 1833 (adapted from Buchinger (1983); source: Döllinger (1838, p. 1519f.))**

Subject	Grade		
	1	2	3
Arithmetic/Algebra	6	6	6
Planimetry	6	-	-
Stereometry	-	6	-
Descriptive Geometry	-	-	6
Graphics	6	12	12
Natural History	6	3	-
Natural Science	-	3	-
Chemistry	-	-	6
Encyclopedia of Industry	3	3	3
Accounting	-	-	3
Hours per Week	27	33	36

**Table 2 - Curriculum of the *Realienunterricht* for the students of the *Gewerbeschule* at the Humanistic *Gymnasium* (adapted from Buchinger (1983); source: Döllinger (1838, p. 1523))**

"Realienunterricht"	Grade		
	1	2	3
Religion	6	4	4
History and Geography	4	6	6
German Grammar	4	-	-
Rhetoric	-	4	4
French (voluntary)	4	4	4
Hours per Week	18	18	18

Students of the agricultural department had to take most of the courses of the curricula in Table 1 although to a lesser extent than their colleagues of the industrial department. In addition their curriculum included agricultural courses such as agricultural economics and animal autonomy. In these courses, theory and practice were linked by practical application in selected businesses (Döllinger, 1838, p. 1519ff.; Buchinger, 1983, p. 123f.).

By the school year of 1835/1836, 30 Landwirtschafts- und Gewerbeschulen were financed by district funds and revenues generated by funds of former Bürgerschulen as listed in (Döllinger, 1838, p. 1625f.).

The technical orientation and the corresponding lack of general education of the Landwirtschafts- und Gewerbeschulen were widely criticized. Especially the rectors of the Bürgerschulen that had to be transformed into Gewerbeschulen stressed the importance of general education. As a consequence, the curricula of many Gewerbeschulen deviated from the official curriculum (cf. Table 1 and Table 2) already in 1833 (Buchinger, 1983, p. 127ff.). For example, the syllabus of the Gewerbeschule in Kaiserslautern contained eleven hours per week of French but only three hours of Chemistry (Buchinger, 1983, p. 136).

In 1864, Landwirtschafts- und Gewerbeschulen were substantially reformed. The weekly hours devoted to general education in form of the Realienunterricht were expanded. The resulting school – henceforth only called Gewerbeschule – provided general education and prepared for a commercial profession. In order to meet the specific needs of their local environment, the Gewerbeschulen were free to set up agricultural and commercial departments (Regierungsblatt, 1864, p. 546ff.; Buchinger, 1983, p. 153ff.). Table 3 shows the curriculum of the reformed Gewerbeschule; this syllabus was obligatory for all students.

**Table 3 - Curriculum of the Reformed Gewerbeschule (adapted from Buchinger (1983); source: Regierungsblatt, 1864, p. 546ff.)**

Subject	Grade		
	1	2	3
Religion	2	2	2
German	5	4	3
Geography	2	2	-
History	2	2	2
Arithmetic	5	-	-
Natural History	4	-	-
Natural Science	-	4	-
Chemistry	-	-	4
Hours per Week	20	14	11

Students had to take additional courses depending on their department. For instance, pupils of the regular Gewerbeschule had to take courses in algebra, geometry and French, stu-

dents at the commercial department lessons in commercial arithmetic, commercial history, French and English, and those at the agricultural department courses in agricultural economics and graphics (Regierungsblatt, 1864, p. 546ff.). As (Kleinfeller, 1883, 39f.) points out, the reformed *Gewerbeschulen* were in fact schools focusing on realistic general secondary education, i.e. the definition of a *Realschule*.

In 1877, the three-year *Gewerbeschulen* were officially transformed into six-year *Realschulen* (Buchinger, 1983, p. 168). The curriculum of the *Realschule* now included an obligatory third language (in this case English), a redefined focus on mathematics and natural sciences such as physics, as well as physical training (Buchinger, 1983, p. 174f.).

The aforementioned Bavarian *Industrieschule* resembled the Bavarian type of the Prussian *Oberrealschule* (Lexis, 1904, p. 103). This institution was established in 1868 as a technical middle-school building up on the *Gewerbeschule* and later on the *Realschule*. Pupils were either prepared for consecutive studies at the *Technische Hochschule* (after having passed the final exam at the end of the second year) or for a career in business and industry (after three years of schooling). The *Industrieschule* comprised three departments focusing on mechanical, technical and constructional techniques. Hence, modern secondary education provided an alternative in entitling for university studies (however, only at the technical university). In 1907, *Industrieschulen* were replaced by *Oberrealschulen* (Buchinger, 1983, p. 105ff.).

Furthermore, the Bavarian schooling system also comprised *Realgymnasien* which can be understood as a compromise between traditional and modern secondary education. Since there existed only four institutions – Augsburg, Munich, Nuremberg and Würzburg – this institution played a rather minor role in secondary education.

All in all, modern secondary schooling in form of the *Gewerbeschule* and *Realschule* provided general education preparing for commercial and industrial professions; the focus on modern languages, applied mathematics and natural sciences uniquely differentiates this school type from the traditional *Gymnasium*.



## **2.2 Advocates of Modern Secondary Schooling**

The educational system of 19th century Germany was subject to profound changes reflecting political, economic and social struggles and movements of that time (Jeismann, 1987, p. 152); thus, the formation of new forms of secondary schooling such as the Realschule, Realgymnasium, Oberrealschule, the Industrieschule and Gewerbeschule can only be understood in light of these movements. As the humanistic Gymnasium with its emphasis on classical languages could not offer an education preparing for commercial and industrial occupations, the mercantile middle class demanded the introduction of so-called realistic schools: the curricula should focus more on modern languages, mathematics and natural sciences (Hamann, 1993, p. 95f.; Ringer, 1967, p. 128f.). These demands were supported by an increasing number of critics who claimed that classical schools such as the humanistic Gymnasium or Lateinschulen could not prepare its pupils for the changes taking place in the scientific, technical, industrial and commercial environment of that time (Albisetti, 1989, p. 182).

Support also came from polytechnic advocacy groups promoting general technical education through journals, lectures, exhibitions, prize competitions and also by setting up special libraries (Kraus, 2008, p. 39f.). In Bavaria for instance, industrial, polytechnic and agricultural associations as well as representatives of industry and commerce, individual persons and the press lobbied for a scientific-technical education in form of polytechnic schools and Gewerbeschulen. A profound scientific-technical education of the labor force was expected to stimulate the economy (Buchinger, 1983, p. 108f.).

## **3 Career Aspirations of Modern Secondary Graduates**

This section analyses the channel through which the Gewerbeschule might influence economic output.

As Ringer (1979, p. 71ff.) shows for Prussia in the years between 1875 and 1899, most graduates of modern schools intended to seek positions in technical occupations such as engineering, mining and architecture or in commerce and industry. In contrast, only a minori-

ty of graduates of the traditional Gymnasium opted for a technical profession or a career in commerce and industry.

Hence, in order to determine the effects of modern secondary education on economic outcomes, precise information about the educational background of the labor force is needed. Lundgreen (1975, p. 70ff.) calculates the percentage distribution of the labor force according to years of schooling for Prussia and shows that in 1864 and 1911 more than 90% of the labor force only attained obligatory elementary education<sup>2</sup> and only a minority continued to secondary schooling and university.

As the subsequent empirical analysis focuses on the effect of the introduction of the Gewerbeschule in Bavaria, exact knowledge about the educational background of the labor force in the years following the introduction would be desirable. In absence of this information, the number of students attending a Landwirtschafts- und Gewerbeschule is an indispensable factor in the analysis as it can be supposed that there is a link between the strength of the effect of the school on economic outcomes and the number of students at this school. The following table lists the number of all students at a Landwirtschafts- und Gewerbeschule during 1836 and 1844.

**Table 4 - Number of Students at the Gewerbeschulen (adapted from Buchinger (1983, p. 145))**

School Year	Number of Schools	Number of Students	Average Number of Students per School
1836/37	30	1288	43
1837/38	31	1245	40
1838/39	32	1197	37
1839/40	26	1102	42
1840/41	25	1038	42
1841/42	24	1105	46
1842/43	26	1191	46
1843/44	26	1359	52

According to Table 4, the overall number of students rose steadily between 1838 and 1844. In 1871/72, the total number of students at the reformed Bavarian Gewerbeschule was

<sup>2</sup> Although elementary schooling was compulsory in Prussia during the whole 19<sup>th</sup> century, school attendance of children did not reach high levels until the end of the century: whereas only 54 % of schooling age children attended school in 1816, their proportion rose to 78% in 1856 and to 85% in 1864 until it reached almost 90% in 1871 (Friederich, 1987, p. 126ff.).

3745, allocated to the respective departments as follows: 3013 at the industrial (“Gewerbeabteilung”), 723 at the commercial (“Handelsabteilung”) and 9 at the agricultural department (“Landwirtschaftsabteilung”) (Beiträge zur Statistik des Königreiche Bayerns, BSKB XXVII). Consequently, this kind of modern secondary education gained in popularity over the years. The number of students at the Gewerbeschule was even higher than at the humanistic Gymnasium and Realgymnasium: the total number of students enrolled in these institution equaled 2640 and 448, respectively (BSKB XXVII.).

Due to the lack of precise data, one can only assume that the career aspirations of students at the Bavarian Gewerbeschule and Realschule corresponded to those of the Prussian students enrolled in modern secondary schooling.

### 3 Econometric Specification and Database

#### 3.1 Econometric Specification

In this paper, I compare counties with a Gewerbeschule or Realschule to counties without modern secondary schooling. However, as mentioned above, assignment of these schools to counties did not occur randomly, thereby limiting the validity of the estimated treatment effect. I will account for this problem by sample restriction using propensity scores in section 3.3.1 and by adopting a differences-in-differences specification in section 3.3.2.

Did the introduction of modern secondary schooling boost economic performance? To answer this question I separately estimate the following models in case of the Gewerbeschule and Realschule:

$$y_{i,t} = \beta_0 + \beta_1 Gew_{i,1835} + \Gamma X_{i,t} + u_{i,t}$$

$$y_{i,t} = \delta_0 + \delta_1 Real_{i,1878} + \delta_2 Real_{i,1896} + \Gamma X_{i,t} + u_{i,t},$$

where  $y_{i,t}$  is a measure of economic performance,  $X_{i,t}$  is a set of control variables including geography, infrastructure, population, existing schools and advocacy groups and  $Gew_{i,1835}$ ,  $Real_{i,1878}$  and  $Real_{i,1896}$  are dummy variables indicating whether there was a Gewerbeschule or Realschule in the respective county. Hence,  $\beta_1$  is the coefficient of interest in case of the Gewerbeschule and  $\delta_1$  and  $\delta_2$  in case of the Realschule.

To account for differential effects that might occur due to the timespan of the existence of a Realschule, I include two dummy variables:  $Real_{i,1878}$  equals one if there was a Realschule in 1878 and  $Real_{i,1896}$  equals one if there was a Realschule in 1896. Thus,  $\delta_2$  captures the effect of having a Realschule in 1896, while  $\delta_1$  captures the additional effect of having had a Realschule since 1878.

The implicit assumption following from this model is that students of modern secondary education do not leave counties after education in order to seek employment or start businesses in other counties.

### 3.2 Database and Main Variables

The main source of data is taken from censuses conducted by the royal Bavarian statistical office (“Königlich-Bayerisches Statistisches Bureau”) between 1850 and 1907 and its predecessor institutions.<sup>3</sup> These censuses were either published in “Beiträge zur Statistik des Königreiche Bayern” (BSKB) or in “Zeitschrift des Königlich Bayerischen Statistischen Bureau“ (ZKBSB).

*Counties.* The observational unit is a county (“Bezirksamt”) implying that cities and their respective counties are combined to one observational unit, i.e. county. This applies to all variables: population numbers, existing schools<sup>4</sup> and measures of economic performance. There are two reasons for merging cities and corresponding counties: First, this allows for the possibility that countryside-children visited city schools and second, it can be supposed that any economic effect of modern secondary schooling was not only restricted to the city, but also to the proximate rural districts. Due to the lack of data I cannot control for migration of graduates.

*Gewerbeschule.* Gewerbeschulen were first introduced in Bavaria 1833 as Landwirtschafts- und Gewerbeschulen. By 1835 there were a total of 30 Gewerbeschulen in Bavaria. The data is based on Gewerbeschulen that received district funds and revenues generated

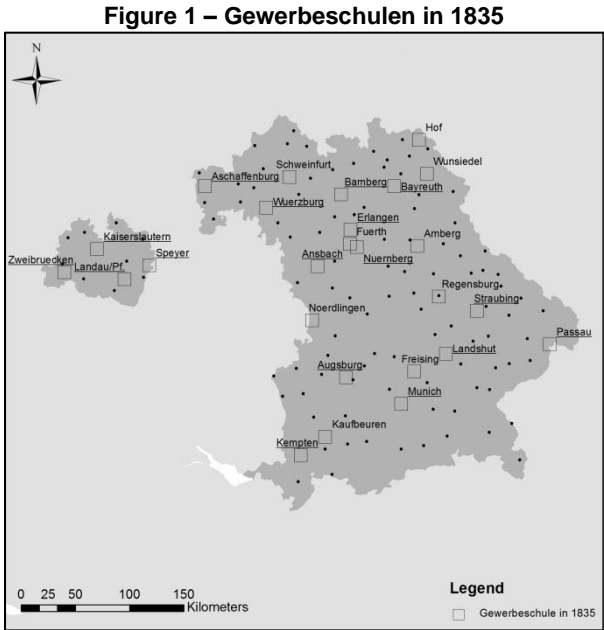
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<sup>3</sup> For more details on the history of the royal Bavarian statistical office see:

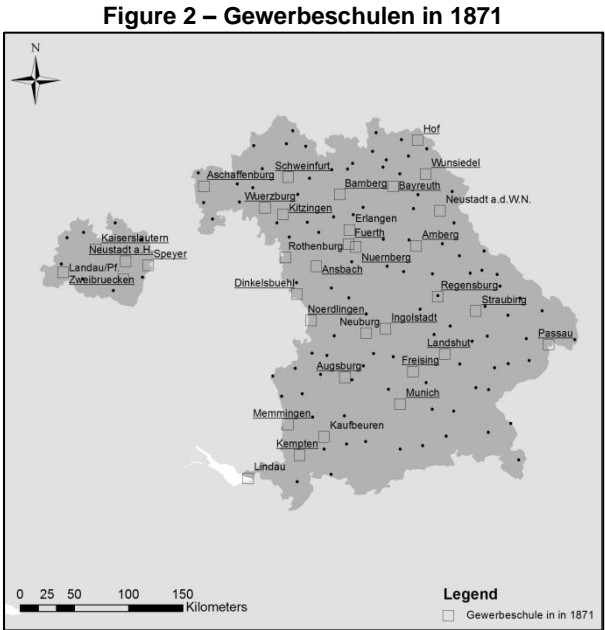
<https://www.statistik.bayern.de/ueberuns/geschichte/>

<sup>4</sup> For instance, the city of Munich opened a Gewerbeschule in 1833 and therefore the whole observational unit consisting of the city and its two counties is counted as having a Gewerbeschule.

by funds of former Bürgerschulen in 1835 as listed in Döllinger (1838, p. 1625f.) and on the list of existing Gewerbeschulen in 1871 in the statistics of education in 1871 (BSKB XXVII). Since the observational unit is a county, once a city opens a Gewerbeschule, the respective observational unit “county” is counted as having a Gewerbeschule. I restrict my sample to those counties that either had a Gewerbeschule both in 1836 and 1871 and to counties that had no Gewerbeschule both in 1836 and 1871. Therefore, counties that set up or closed a Gewerbeschule in the years between 1836 and 1871 are excluded from the sample. Counties with a Gewerbeschule in 1835 and 1871 are shown by Figure 1 and 2, respectively. The dots without a name correspond to the counties in the control group.



**Notes: County name is underlined if population in 1840 exceeds 25,000.**



**Notes: County name is underlined if population in 1871 exceeds 30,000.**

As can be seen from comparing Figure 2 to 1, nine Gewerbeschulen opened between 1835 and 1871<sup>5</sup> and are therefore excluded from the sample used to estimate the effect of the Gewerbeschule. Dillingen, Ingolstadt and Rothenburg had a Gewerbeschule in 1835 (Döllinger, 1838, p. 1625f.) but are also excluded since they had to close their schools in the

<sup>5</sup> Counties that set up a Gewerbeschule between 1835-1871 were: Dinkelsbühl, Lindau (opened 1859; Keyser and Stooß, 1974, p. 349), Kitzingen (opened 1871, Keyser and Stooß, 1971, p. 82), Memmingen, Neuburg a.d.D. (opened 1859; Keyser and Stooß, 1971, p. 458) and Neustadt a.d.H., Neustadt a.d.W.N.

meantime.<sup>6</sup> Schwabach is stated in Döllinger (1838, p. 1625f.) as a recipient of funds for a Gewerbeschule in 1835 but according to Keyser and Stoob (1971, p. 82) the Gewerbeschule was founded only in 1871. Hence, Schwabach is also excluded from the Gewerbeschule sample. Consequently, the sample used to estimate the impact of the Gewerbeschule comprises 26 “treated” counties. However, all counties with a Gewerbeschule in 1871 will be included as covariates in the Realschule sample (corresponding to all counties depicted by Figure 2, in total 36).

*Other Controls.* Data on population numbers are taken from censuses in 1840, 1871, 1880 and 1905. Data on Advocacy Groups and on savings banks are from contributions to the Bavarian statistics (“Beiträge zur Statistik des Königreichs Bayern”) in 1872 and 1873, respectively. Data on financial institutions and administrative independence originate from the city book (Keyser and Stoob, 1971) and ministry manual (Volkert, 1983), respectively. The location of existing Humanistische Gymnasien in 1862 and 1906 is taken from education statistics in 1862 (BSKB XIV) and Ministerialblätter (1906), respectively. Data on other existing (traditional) schools come from contributions to the Bavarian statistics concerning the school system in 1862 and 1871 (BSKB IV, XXVII).

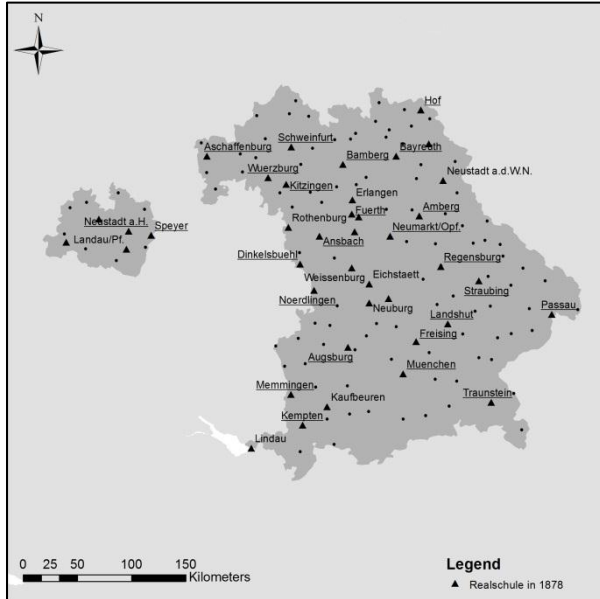
*Realschule.* Realschulen were introduced in 1877 in Bavaria and replaced all existing forty Gewerbeschulen. By the school year of 1906/07 another 15 Realschulen had been opened in 13 counties. Except for Munich and Nürnberg which opened additional Realschulen, all new Realschulen were opened in cities that previously had not offered modern secondary education.<sup>7</sup> Unlike the Gewerbeschule, there is no case of a Realschule documented that had to close in the subsequent years. The data is based on Buchinger (1983) who provides a list of all Realschulen based on the Ministerialblätter published by the Bavarian Ministry of State (MB 1886). Counties with a Realschule in 1878 and 1896 are shown by Figure 3 and 4, respectively. The dots without a name correspond to counties in the control group.

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<sup>6</sup> Only Ingolstadt and Rothenburg reopened them in 1858 and 1865, respectively (Keyser and Stoob, 1871, p. 471; Keyser and Stoob, 1874, p. 278).

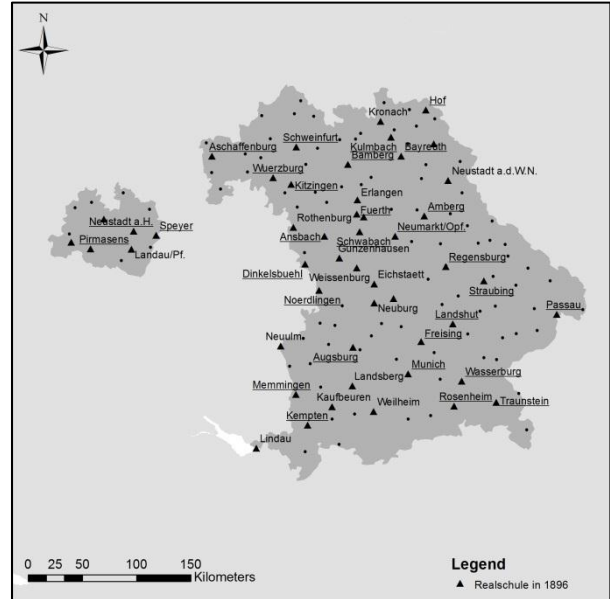
<sup>7</sup> In 1906/07 Munich had four and Nürnberg two Realschulen.

Figure 3 – Realschulen in 1878



Notes: County name is underlined if population exceeds 30,000 in 1871.

Figure 4 – Realschulen in 1896



Notes: County name is underlined if population exceeds 30,000 in 1871.

*Economic Performance.* Investments in schooling can be supposed to have a lagged effect on the economy. Therefore, I focus on measures capturing economic performance with a time lag. As outlined in section 2.1, the curricula of modern secondary education focused on applied teaching of mathematics such as commercial arithmetic and modern languages, I adopt measures capturing the trade business environment. Furthermore, the curricula included subjects that can be supposed to be beneficial for industrial occupations such as planimetry, chemistry and natural science; hence I also use measures of industrial performance.

In case of the *Gewerbeschule* I use three measures: the average number of net registrations of businesses per year, the number of self-employed in industry and trade and the number of employees in services and industry. The average number of net registrations of trade businesses per year is captured by taking the average difference between the number of registrations and deregistrations within one year in one county (“*Handelsgewerbebewegung*”). I focus on the time period between 1869 and 1875. The data are taken from industrial censuses (ZKBSB 12). The number of business net-registrations within one year provides information about the dynamics and quality of the business environment and hence is a proxy for economic performance of a county. The number of self-employed in 1871 and the data on employees in industry and services in 1882 are taken from occupational censuses (BSKB XXXXVIII & BSKB L). It can be supposed that the higher the number of people

self-employed in industry and trade as well as people working in services and industry, the higher is the industrial development of a county.

In case of the Realschule I also use three measures: the number of trade and industrial businesses, the number of employees in trade and industry and the average number of new patents. I concentrate on the number of existing businesses in 1907 in two main categories, i.e. trade and industry. Furthermore, I use two sub-categories of industry, i.e. chemical industry and machinery. I suppose that counties with a Realschule had more businesses and people employed in these sectors as modern secondary schools provided educational training required for these occupations. The data on businesses and employees is taken from the establishment census in 1907 (ZKBSB LXXXII). As a final measure I employ the average number of newly granted patents between 1902 and 1913. I use the Baten/Streb patents database (Streb et al., 2006). The database includes all patents granted between 1877 and 1918 that were economically valuable, indicated by the lifespan of a patent. Since patent holders had to pay annual renewal fees to maintain the patent, Baten and Streb argue that a patentee would only do so if patenting provided economic benefits (Streb et al., 2006, p. 349f.).

*Other Controls.* Data on population numbers are taken from censuses in 1840, 1871, 1880 and 1905. Data on Advocacy Groups and on savings banks are from contributions to the Bavarian statistics (“Beiträge zur Statistik des Königreichs Bayern”) in 1872 and 1873, respectively. Data on financial institutions and administrative independence originate from the city book (Keyser and Stoob, 1871) and ministry manual (Volkert, 1983), respectively. The location of existing Humanistische Gymnasien in 1862 and 1906 is taken from statistics of education (BSKB XIV) and Ministerialblätter (1906), respectively. Data on other existing (traditional) schools come from contributions to the Bavarian statistics (“Beiträge zur Statistik des Königreichs Bayern”) concerning the school system in 1862 and 1871.

### **3.3 Dealing with Endogeneity**

As Figures 1 to 4 show, Gewerbeschulen and Realschulen were opened in most instances in big, prosperous and economically developed counties; this is especially true in case of



the Gewerbeschule: the three largest Bavarian cities in population in 1840 – Munich, Landau (Pfalz) and Nürnberg – all opened a Gewerbeschule.<sup>8</sup> After all, it was the Bavarian King Ludwig I himself who demanded the opening of a Gewerbeschule in all big cities (Döllinger, 1838, p. 1691). In case of the Realschule, Figure 3 implies a less strong relationship between economic development and population of a county and the opening of a Realschule. However, the difference in population between counties opening and not opening one in 1871 is still positive and significant on the 1%-level.<sup>9</sup>

Therefore, the introduction of modern secondary education was driven by endogenous factors (such as population size<sup>10</sup> and economic prosperity) and will lead to biased and inconsistent OLS estimates. Here, endogeneity is likely to arise from two sources: reverse causality and omitted variables.

Reverse causality would imply that especially the prosperous counties or cities opened a Gewerbeschule and/or later a Realschule. This is in line with Diebolt and Fontvieille (2001) who argue that in case of Germany and France, human capital investments prior to 1945 were a response to economic growth.<sup>11</sup> Consequently, the adopted econometric specification in chapter 3.1 is not able to determine a causal relationship between economic performance and the introduction of the Gewerbeschule. However, it implicates that there exists a positive correlation between these two variables. In the following two chapters, econometric methods will be introduced to alleviate potential endogeneity problems.

### 3.3.1 Propensity Scores

An alternative econometric specification that can be adopted to estimate the economic effect of modern secondary education is propensity score matching as proposed by Rosenbaum and Rubin (1983). Propensity score matching uses observational characteristics

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<sup>8</sup> Gewerbeschulen were opened in counties with an average population of 359655.88 vs. 18023.33 in counties that not opened a Gewerbeschule in 1840. Thus, the difference between these two groups yielded by two-sample T-test amounts to 17942.55 people and is significant on the 1%-level.

<sup>9</sup> The difference in average population obtained by a two-sample T-test is -23014.49, implying that counties with a Realschule were significantly bigger than counties without one (49708.95 vs. 26694.46).

<sup>10</sup> In fact, population size, population density and urbanization are frequently used in the literature as a proxy for economic development (cf. Acemoglu et al., 2012).

<sup>11</sup> According to North and Thomas (1973, p. 2), education is not a cause of economic growth, it is growth itself.

to estimate the probability of treatment in terms of the propensity score (which is strictly between 0 and 1). Individuals are then matched according to their propensity scores and treatment effects can be estimated by comparing alike individuals – based on observable characteristics – with and without treatment. This approach enables estimation of treatment effects if treatment is not assigned randomly.

In case of the Gewerbeschule and Realschule this means that additional county characteristics prior to the opening of these schools are needed. These characteristics – comprising for example city size, measures reflecting economic development, religion, number and type of existing schools, universities, public health sector, local business associations, and etcetera – then help to predict the opening of a Gewerbeschule and/or Realschule. By accounting for these additional variables it is possible to circumvent the endogeneity associated with the introduction of these schools and hence estimate a consistent effect on economic outcomes.

I use several variables to predict the introduction of modern secondary education. In case of the introduction of a Gewerbeschule by 1835, these are population structure in 1840<sup>12</sup> (including share of children, religious affiliations and stationed military), administrative independence in 1830, geography (dummy variable for Bavarian Palatine, an exclave lying west of the Rhine), advocacy groups for education and economy in 1839<sup>13</sup>, economic development in 1840 (proxied by employment structure) and financial development in 1835 (proxied by the existence of a savings bank). Characteristics predicting the opening of a Realschule by 1896 include population structure in 1871 (religious affiliations and stationed military), administrative independence in 1871, geography (dummy variable for Bavarian Pfalz), advocacy groups for education, economy and science in 1872, economic development in 1871 (proxied by number of self-employed in trade and industry) and other existing schools 1871 (Lateinschule and Gymnasium).

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<sup>12</sup> Due to the lack of available data, I use the “Volkszählung” of 1840 (BSKB I), although this is several years after the introduction of the Gewerbeschule in 1829 and the respective openings in counties between 1833 and 1835.

<sup>13</sup> Unfortunately, the available data only provides the number of advocacy groups for each decade.

Propensity scores are then calculated using a probit regression based on the respective county characteristics. Table 5 and 6 depict propensity scores for the introduction of the Gewerbeschule by 1835 and Realschule by 1896, respectively.

**Table 5 - Propensity Scores “Introduction of Gewerbeschule by 1835”**

County	Prop. Score	Gew 1835	County	Prop. Score	Gew 1835	County	Prop. Score	Gew 1835	County	Prop. Score	Gew 1835
Kusel	1.57E-10	0	Obernburg	0.0002465	0	Stadtamhof	0.00564882	0	Kaiserslautern	0.45123668	1
Feuchtwangen	7.397E-10	0	Beilngries	0.000274	0	Vilsbiburg	0.00577924	0	Speyer	0.50481166	1
Neuulm	7.444E-10	0	Gerolzhofen	0.00034069	0	Aichach	0.0060004	0	Germersheim	0.54654626	0
Ebermannstadt	7.421E-09	0	Waldmuenchen	0.00040183	0	Friedberg	0.00776956	0	Kaufbeuern	0.62904575	1
Marktheidenfeld	1.695E-08	0	Kehlheim	0.00049445	0	Deggendorf	0.00863467	0	Zweibruecken	0.69628186	1
Gunzenhausen	2.174E-07	0	Neumarkt	0.00058634	0	Burglengenfeld	0.00967336	0	Kempton	0.7403206	1
Sulzbach	3.389E-07	0	Wolfstein	0.00059623	0	Freising	0.01477972	1	Eichstaett	0.8815809	0
Ebern	4.611E-07	0	Brueckenau	0.00067487	0	Dachau	0.01750575	0	Landshut	0.88891534	1
Forchheim	6.341E-07	0	Grafenau	0.00067813	0	Wertingen	0.01894067	0	Wunsiedel	0.91672999	1
Uffenheim	0.000001685	0	Viechtach	0.00072822	0	Dingolfing	0.01923297	0	Straubing	0.92553182	1
Hersbruck	0.000004084	0	Bogen	0.00072924	0	Landau NB	0.02194617	0	Schweinfurt	0.95781309	1
Karlstadt	0.000004147	0	Hassfurt	0.00077826	0	Eschenbach	0.02534069	0	Amberg	0.96671162	1
Ochsenfurt	0.0000049	0	Altoetting	0.00114377	0	Regen	0.02661892	0	Landau	0.96719291	1
Melrichstadt	0.00000515	0	Hammelburg	0.00116846	0	Traunstein	0.02669352	0	Aschaffenburg	0.98747685	1
Pfarrkirchen	0.000006608	0	Ebersberg	0.00118243	0	Illertissen	0.03019956	0	Hof	0.98778477	1
Kulmbach	0.000009418	0	Wasserburg	0.00118968	0	Miltenberg	0.03933754	0	Noerdlingen	0.99541633	1
Hoechstadt	0.000009836	0	Rottenburg	0.0017213	0	Cham	0.03977072	0	Ansbach	0.99641537	1
Miesbach	0.00001182	0	Koetzing	0.00204177	0	Kemnath	0.04152793	0	Fuerth	0.99777476	1
Toelz	0.00001293	0	Neustadt a.d.S.	0.002265	0	Krumbach	0.05214097	0	Erlangen	0.99912691	1
Tirschenreuth	0.00001389	0	Stadtsteinach	0.00236657	0	Muenchberg	0.05295977	0	Bayreuth	0.99999642	1
Koenigshofen	0.00001612	0	Eggenfelden	0.00243651	0	Vilshofen	0.05300396	0	Passau	0.99999979	1
Fuessen	0.00002224	0	Roding	0.00298765	0	Weissenburg	0.07056789	0	Regensburg	0.99999982	1
Griesbach	0.00002285	0	Laufen	0.00301985	0	Landsberg	0.07376489	0	Augsburg	1	1
Alzenau	0.00003884	0	Muehldorf	0.00308007	0	Kronach	0.08393671	0	Nuernberg	1	1
Heilsbronn	0.00005147	0	Rosenheim	0.00318161	0	Primasens	0.08396556	0	Wuerzburg	1	1
Nabburg	0.00009205	0	Neunburg v./W.	0.0033878	0	Vohenstrauß	0.0885276	0	Bamberg	1	1
Donauwoerth	0.00010729	0	Weilheim	0.00343122	0	Guenzburg	0.11446692	0	Muenchen	1	1
Sonthofen	0.00011284	0	Pfaffenhofen	0.0034525	0	Mindelheim	0.11967273	0	0	0	0
Berneck	0.00016717	0	Erding	0.00364939	0	Lichtenfels	0.12169397	0	0	0	0
Lohr	0.00019007	0	Schongau	0.00394871	0	Bergzabern	0.16355072	0	0	0	0
Schrobenhausen	0.00021281	0	Naila	0.00541374	0	Frankenthal	0.2573832	0	0	0	0
Hemau	0.00023576	0	Rehau	0.00556483	0	Frankenthal	0.28293294	0	0	0	0

Notes: Table reports propensity scores predicting the introduction of a Realschule by 1896 using probit regression based on population structure (i.e. total population and population shares of kids, catholics, protestants, jews and military)(1840), administrative independence (1830), geography, economic development (1840), advocacy groups (1839) and financial development (1835). Propensity scores lie strictly between 0 and 1, depicted propensity scores are rounded to 8 decimal figures. Framed counties with propensity scores 0.01-0.9 will be used in the restricted sample.

**Table 6 - Propensity Scores “Introduction of Realschule by 1896”**

County	Prop. Score	Real 1896	County	Prop. Score	Real 1896	County	Prop. Score	Real 1896	County	Prop. Score	Real 1896	County	Prop. Score	Real 1896
Mellichstadt	0.00304333	0	Gerolzhofen	0.03800311	0	Neuulm	0.0974221	1	Neustadt a.A.	0.35296232	0	Straubing*	0.98564202	1
Neustadt a.d.S.	0.00843566	0	Burglengenfeld	0.03899998	0	Lohr	0.09757696	0	Traunstein*	0.35775486	1	Freising*	0.98916192	1
Ebern	0.01434081	0	Kemnath	0.03969435	0	Rehau	0.10036641	0	Guenzburg	0.35977948	0	Speyer*	0.98955421	1
Toelz	0.01814246	0	Friedberg	0.04032511	0	Wasserburg	0.10087728	1	Hersbruck	0.36556372	0	Aschaffenburg*	0.99182795	1
Fuessen	0.01850867	0	Regen	0.04266113	0	Bruck	0.10161794	0	Germersheim	0.38566521	0	Fuerth*	0.99301241	1
Werdenfels	0.01884523	0	Ebersberg	0.04299127	0	Vilshofen	0.103188	0	Kulmbach	0.42537721	1	Kempten*	0.99602045	1
Ebermannstadt	0.01890541	0	Obernburg	0.04505075	0	Hemau	0.10405265	0	Landau/Pf.*	0.44948593	1	Landshut*	0.99648461	1
Bruckenaau	0.01912395	0	Koetzing	0.04667844	0	Marktheidenfeld	0.1106639	0	Mindelheim	0.4528802	0	Schweinfurt*	0.99976075	1
Grafenau	0.01958645	0	Illertissen	0.04718562	0	Landau	0.11563716	0	Aichach	0.46330483	0	Memmingen*	0.99978145	1
Weilheim	0.02027423	1	Teuschnitz	0.04777031	0	Deggendorf	0.11652466	0	Sonthofen	0.48511248	0	Ansbach*	0.99994654	1
Wertingen	0.02201151	0	Cham	0.04824631	0	Erding	0.11801038	0	Pirmasens	0.59567524	1	Passau*	0.99998908	1
Zusmarshausen	0.02246377	0	Eschenbach	0.0498595	0	Sulzbach	0.12496385	0	Landsberg*	0.6188067	1	Erlangen*	0.9999997	1
Krumbach	0.02288101	0	Laufen	0.05172907	0	Naila	0.12537976	0	Zweibruecken*	0.63455317	1	Neustadt a.H.*	0.99999991	1
Oberdorf	0.02306221	0	Velburg	0.05433441	0	Vilsbiburg	0.12647173	0	Uffenheim	0.63914562	0	Bayreuth*	0.99999998	1
Dingolfing	0.0252544	0	Beilngries	0.05602028	0	Berneck	0.13821634	0	Kaiserslautern*	0.68334875	1	Regensburg*	1	1
Wolfstein	0.02533846	0	Heilsbronn	0.06377406	0	Homburg	0.15237622	0	Donauwoerth	0.68717758	0	Bamberg*	1	1
Berchtesgaden	0.02558108	0	Bogen	0.06547661	0	Muehldorf	0.15397508	0	Rothenburg*	0.81949233	1	Nuernberg*	1	1
Alzenau	0.02576569	0	Pfarrkirchen	0.06609968	0	Hammelburg	0.16297998	0	Wunsiedel*	0.82056206	1	Augsburg*	1	1
Muenchenberg	0.02607844	0	Vohenstrauß	0.06691045	0	Griesbach	0.16406564	0	Rosenheim	0.82191484	1	Muenchen*	1	1
Staffelstein	0.02680385	0	Hoechstadt	0.07161506	0	Scheinfeld	0.17599212	0	Eichstaett*	0.82221192	1	Wuerzburg*	1	1
Schongau	0.02817417	0	Koenigshofen	0.0737	0	Forchheim	0.18585267	0	Lindau*	0.8290553	1			
Karlstadt	0.02848169	0	Stadtamhof	0.07507149	0	Frankenthal	0.18881265	0	Weissenburg*	0.83899064	1			
Waldmuenchen	0.02906977	0	Mallersdorf	0.07892795	0	Kusel	0.20729532	0	Kaufbeuren*	0.84006611	1			
Wegscheid	0.03006102	0	Pfaffenhofen	0.07987561	0	Kissingen*	0.20883789	1	Dillingen	0.87385977	0			
Hassfurt	0.03052016	0	Eggenfelden	0.080765	0	Miltenberg	0.21412097	0	Amberg*	0.88710551	1			
Nabburg	0.03058262	0	Neustadt a./WN.*	0.08181662	1	Altoetting	0.23915154	0	Dinkelsbuehl*	0.93037039	1			
Roding	0.03113035	0	Stadtsteinach	0.08604281	0	Gunzenhausen	0.24284343	1	Neuburg*	0.94742954	1			
Viechtach	0.03222001	0	Neumarkt*	0.08858845	1	Feuchtwangen	0.24425449	0	Kitzingen*	0.95358303	1			
Schrobenhausen	0.03246891	0	Neunburg v.W.	0.08916118	0	Rottenburg	0.24860873	0	Hof*	0.9696598	1			
Miesbach	0.03474337	0	Kronach	0.09187803	1	Kelheim	0.29092766	0	Schwabach*	0.97698994	1			
Dachau	0.03674903	0	Tirschenreuth	0.0938694	0	Bergzabern	0.30679122	0	Noerdlingen*	0.97863117	1			
Ochsenfurt	0.03728654	0	Lichtenfels	0.09657823	0	Kirchheimbolander	0.30951522	0	Ingolstadt*	0.98127315	1			

Notes: Table reports propensity scores predicting the introduction of a Realschule by 1896 using probit regression based on population structure (i.e. total population and population shares of catholics, protestants, jews and military) (87), administrative independence (87), geography (Bavarian Palatine), economic development (87), advocacy groups (87) and other schools (i.e. Lateinschulen and/or Lateingymnasien) (87). Propensity scores lie strictly between 0 and 1; depicted propensity scores are rounded to 8 decimal figures. Framed counties with propensity scores 0.10-0.9 will be used in the restricted sample.

According to Table 5, the majority of counties have a relatively low probability of opening a Gewerbeschule. Except for Freising (which opened one despite having a low propensity score), Eichstätt and Germersheim (which both did not open one despite having a high propensity score), the sample is divided into two kinds of counties: those with low propensity scores and no Gewerbeschule and those with high propensity scores and a Gewerbeschule. Thus, the calculated propensity scores confirm the apprehension of section 3.3 implying that the introduction of a Gewerbeschule was driven by endogenous factors.<sup>14</sup>

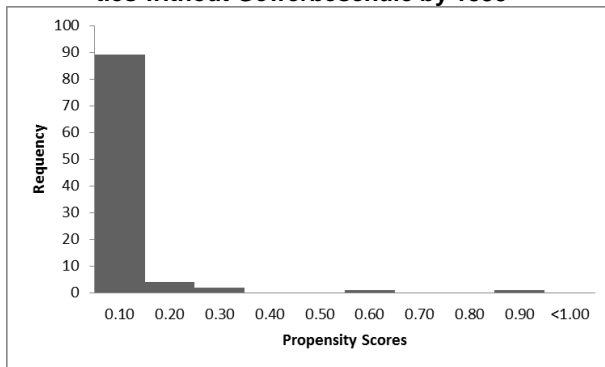
Propensity scores for the introduction of the Realschule in Table 6 are less divided between treated and non-treated counties: five counties with a propensity score less than 0.1 (i.e. Weilheim, Neustadt a./WN., Neumarkt, Kronach and Neuulm) opened a Realschule whereas two counties with a score above 0.6 (i.e. Donauwörth and Dillingen) did not open one. This implicates that the introduction of a Realschule did not entirely depend on econom-

<sup>14</sup> Probit regression used to predict the introduction of a Gewerbeschule implicates that administrative independence and advocacy groups lobbying for education played a significant (positive) role in deciding whether a county opened this school or not.

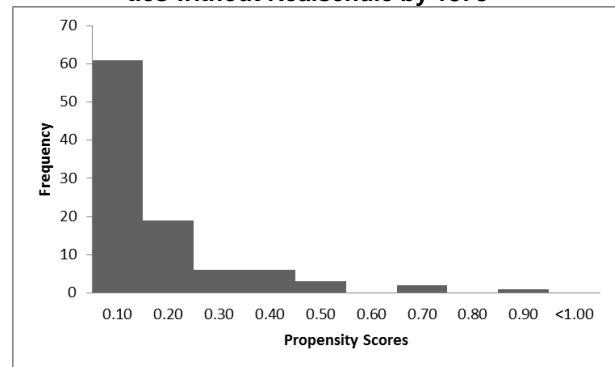
ic – and therefore endogenous – reasons.<sup>15</sup> Thus, the introduction of the Realschule exhibits a higher of randomness than the introduction of the Gewerbeschule.

Figures 5 to 8 display corresponding histograms of the frequency distribution of the propensity scores for treated and control groups.

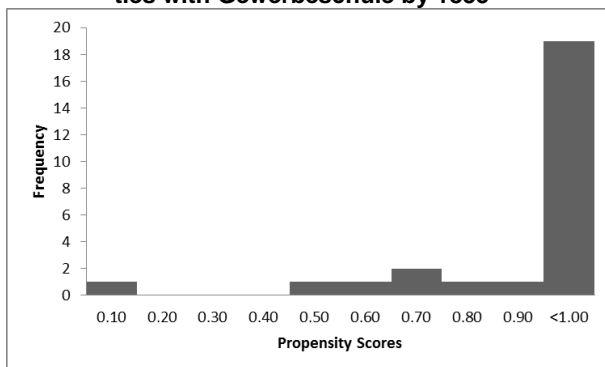
**Figure 5 – Histogram Propensity Scores for counties without Gewerbeschule by 1835**



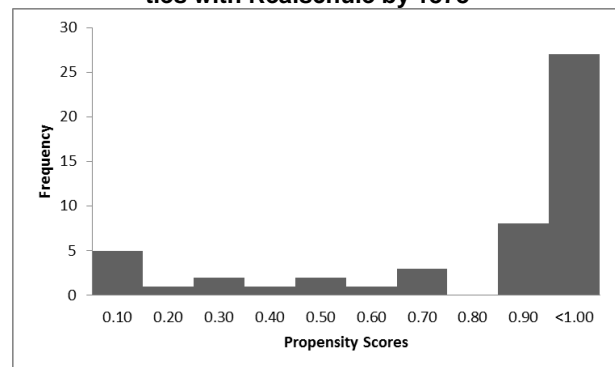
**Figure 7 – Histogram Propensity Scores for counties without Realschule by 1878**



**Figure 6 – Histogram Propensity Scores for counties with Gewerbeschule by 1835**



**Figure 8 – Histogram Propensity Scores for counties with Realschule by 1878**



According to Figures 5 and 6, there exists a considerable lack of overlap between the control and treatment group in the Gewerbeschule sample. In case of the Realschule, Figures 7 and 8 indicate some – albeit very low – degree of overlap.

Hence, conducting traditional propensity score matching using matching methods does not seem feasible in this case.<sup>16</sup> Crump et al. (2006) suggest restricting samples with clear lack of overlap of propensity scores between treated and control groups from 0.1 to 0.9. In

<sup>15</sup> Probit regression used to predict the introduction of a Realschule implicates that administrative independence, total population and advocacy groups lobbying for education and science played a significant (positive) role in deciding, whether a county opened this school or not. The population share of self-employed in industry and trade did not significantly influence the prospect of an opening.

<sup>16</sup> In case of the Gewerbeschule and Realschule, propensity score matching still yields 6 balanced blocks indicating that there is no difference in controls and propensity scores between treated and control variables. However, the size of blocks differs from only 2 to 99 (Gewerbeschule) and 5 to 87 (Realschule) observations.

case of the Gewerbeschule, the number of observations would shrink to a mere 14 (7 treated). Therefore, I restrict the Gewerbeschule sample to counties with corresponding propensity scores between 0.01 and 0.9. The resulting sample then comprises 34 observations, with 7 of them treated. In case of the Realschule I follow Crump et al. (2006) and restrict the sample to observations with corresponding propensity scores between 0.1 and 0.9. This yields a sample with 55 counties<sup>17</sup> (18 treated) (corresponding to all framed counties in Table 6).

### 3.3.2 Differences-in-Differences Estimation

Another approach that can be adopted to deal with endogeneity is a differences-in-differences estimation. Rather than comparing outcomes between the treated and control group, this method compares the change in outcomes between a pre-treatment and a post-treatment period across groups. Any observed and unobserved time-invariant heterogeneity between the treatment and control group are then irrelevant and will no longer bias the estimates. By employing this approach, all observed and unobserved differences between those counties introducing modern secondary schooling and those not introducing, would be filtered out as long as these differences do not vary over time (e.g. economic spirit).

Hence, conducting a differences-in-differences estimation requires outcome data before and after treatment. This implies that in case of the Gewerbeschule and Realschule data for time periods before 1833 and 1877, respectively, would be needed. To the best of my knowledge, there is no such data available for the Gewerbeschule. However, in case of the Realschule, data on yearly registrations and deregistrations of trade businesses<sup>18</sup> is available from 1868 to 1913. I focus on the time period from 1873 to 1876 (pre-treatment) and from 1903 to 1906 (post-treatment). As in case of the Gewerbeschule (cf. 3.3), I calculate the average number of business net registrations per county of the respective time-period. This

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<sup>17</sup> Note that three observations (i.e. Hemau, Velburg and Heilsbronn) will not be used in the subsequent empirical analyses due to the lack of data resulting from local government reorganizations. In 1880 Hemau and Velburg were merged to one county, i.e. Parsberg (Volkert, 1983, p. 546) and Heilsbronn was dissolved (Volkert, 1983, p. 480). All three counties are used in the calculation of propensity scores but are disregarded from subsequent regressions estimating economic effects after 1880.

<sup>18</sup> Note that the average number of business net registrations between 1869 and 1875 is employed as an outcome measure for the Gewerbeschule (cf. section 3.2).

data is then combined with data on population in 1871 (pre) and 1905 (post), administrative independence in 1871 (pre) and 1906 (post), and a Gymnasium<sup>19</sup> dummy for 1871 (pre) and 1906 (post) to form a panel structure. Treatment is the opening of a Realschule by 1896 in a county. The structure of the model with the differences-in-differences estimator  $\beta_1$  is:

$$y_{i,t} = \mu_i + \beta_1 Realschule_{i,t} + \beta_2 Post_t + \Gamma X_{i,t} + u_{i,t}$$

where  $y_{i,t}$  is the number of average business net registrations in county  $i$  at time  $t$ ,  $\mu_i$  are county fixed-effects,  $Post_t$  is a dummy variable that equals 1 at time  $t$  and  $X_{i,t}$  is a set of control variables including geography, administrative independence, population and traditional secondary education (i.e. Gymnasium). The coefficient of interest is  $\beta_1$  which captures the average economic effect of having opened a Realschule by 1896 between counties with a Realschule by 1896 and those without.

## 4 Empirical Results

This section explains the empirical results obtained by OLS-regressions and those obtained by empirical approaches employed to alleviate potential endogeneity biases.

### 4.1 Economic Impact of the Gewerbeschule

The economic impact of the introduction of a Gewerbeschule in a county is presented by Table 7. In the first row, results for Panel A, i.e. an OLS regression without any control variables, are shown. The impact of the Gewerbeschule on all dependent variables is significant on the 1%-level or 5%-level: introduction of the Gewerbeschule by 1835 is associated with more people self-employed in trade and industry in 1871 (column 1 and 2), more employees in services and industry in 1882 (column 5 and 6), and a higher average number of net registrations of businesses 1869-1875 (column 7). Panel B includes geography (i.e. a dummy variable for counties in the Bavarian Pfalz), infrastructure (i.e. a dummy variable for administrative independence in 1871) and population structure in 1871 (columns 1,2 and 7) and 1880 (column 7). Except for the number of self-employed in industry (column 2) and the

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<sup>19</sup> This dummy equals one if the county offers traditional secondary education, i.e. Gymnasium and/or Lateinschule (later called Progymnasium).

number of employees in services (column 3) – which is negatively correlated with the Gewerbeschule – the significant effects vanish. More variables controlling for Gymnasien in 1862 and advocacy groups in 1872 are added in Panel C. Hence, Panel C controls for the widest range of socio-economic factors – in fact potential endogenous factors themselves – in Table 7 and in all following regressions. Once again, the Gewerbeschule is positively and significantly correlated with the number of self-employed in industry (column 2). The negative effect on the number of employees in services is insignificant and smaller compared to Panel B (column 5). However, these results are likely to be biased by endogeneity problems. I will deal with this problem in section 4.3 below.

**Table 7 - Economic Effect of the Gewerbeschule (Introduction by 1835)**

Dependent Variable:	<u>Number Self-Employed (1871) in</u>		<u>Number of Employees (1882) in</u>		<u>Average Number of</u>
	Trade (1)	Industry (2)	Services (5)	Industry (6)	<u>Net-Registrations</u> (1869-1875) (7)
<b>Panel A: no controls</b>					
Gewerbeschule 1835	574.2*** [180.2]	1,996*** [516.4]	2,745*** [991.1]	7,891*** [2,410]	50.35** [25.06]
<b>Panel B: small set of controls</b>					
Gewerbeschule 1835	40.05 [108.0]	505.2* [297.7]	-699.5*** [236.5]	-517.0 [434.7]	-14.17 [8.651]
<b>Panel C: large set of controls</b>					
Gewerbeschule 1835	130.6 [119.4]	754.3** [373.6]	-272.5 [200.0]	305.4 [626.4]	-4.389 [7.856]
Observations	127	127	124	124	128

Notes: Table reports OLS estimates. Unit of observation is a county. Robust standard errors are in parentheses: significantly different from 0 at \*\*\*1%, \*\*5% and \*10% level. Panel A includes no controls. Panel B includes geography (Pfalz), administrative independence (1871) and population structure (i.e. total and population shares of Catholics, Protestants, Jews and military) (1871 or 1880) as controls. Panel C includes geography (Pfalz), administrative independence (1871), population structure (1871 or 1880), traditional schools (1862) and advocacy groups (1872) as controls.

## 4.2 Economic Impact of the Realschule

Table 8 reports the estimated impact of the Realschule obtained by OLS. The table follows the same structure as Table 7: Panel A includes no controls, Panel B adds Geography (i.e. a dummy variable for Bavarian Pfalz), administrative independence in 1896 and population structure (total and shares of religious affiliations) in 1905 and Panel C once again controls for other school types such as Gewerbeschule (1871), Industrieschule (1884), Technische Hochschule (1884), University (1884), Gymnasium (1906) and Progymnasium (1906) and also advocacy groups in 1872 lobbying for science, education and economy. As outlined in section 3.1 I differentiate between Realschulen that were introduced in the school year of



1877/1878 and after 1878 (until 1896). Estimates corresponding to the latter are given in the second row of each Panel. First-row estimates of Panel A are all positive and significant. For example, counties which opened a Realschule in 1878 (between 1878 and 1896) are associated with 2,020 (1,176) more businesses in industry than counties without a Realschule. However, these positive significant effects vanish if more control variables are added to the sample. Estimates in Panel B and C are in most cases insignificant and negative, thereby implying that counties with modern secondary education did economically worse than counties without this school type.

**Table 8 - Economic Effect of the Realschule (Introduction by 1878 or 1896)**

Dependent Variable:	<u>Number of Businesses (1907) in</u>				<u>Number of Employees (1907) in</u>		<u>Average</u>
	Trade	Industry	Chemical Indus.	Machinery	Trade	Industry	<u>Number of new Patents (1902-1913)</u>
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
<b>Panel A: no controls</b>							
Realschule 1878	1,645*** [521.0]	2,020*** [639.4]	20.13*** [7.574]	83.26*** [25.41]	4,279** [1,663]	12,337*** [3,738]	1.507** [0.704]
Realschule 1896	493.4** [226.0]	1,176** [561.6]	5.385 [3.592]	34.86 [22.95]	855.5** [424.5]	4,510** [2,232]	0.118 [0.0813]
<b>Panel B: small set of controls</b>							
Realschule 1878	-199.4** [92.17]	-284.8** [143.0]	-4.493 [3.563]	-12.20 [7.667]	-1,098*** [396.4]	19.38 [1,018]	-0.637** [0.276]
Realschule 1896	-28.38 [145.4]	494.9 [372.0]	-1.741 [3.554]	7.439 [17.25]	-543.8* [319.2]	939.3 [1,500]	-0.419** [0.193]
<b>Panel C: large set of controls</b>							
Realschule 1878	-45.83 [103.3]	-195.6 [130.5]	-3.525 [3.242]	-16.64 [10.65]	-367.1 [260.9]	-1,763** [811.3]	-0.350 [0.271]
Realschule 1896	11.47 [166.9]	627.8 [402.3]	-5.045 [4.352]	13.37 [18.71]	-244.5 [352.3]	389.7 [1,569]	-0.405 [0.295]
Observations	145	145	145	145	145	145	145

Notes: Table reports OLS estimates. Unit of observation is a county. Robust standard errors are in parentheses: significantly different from 0 at \*\*\*1%, \*\*5% and \*10% level. Panel A includes no controls. Panel B includes geography (Pfalz), administrative independence (1896), population (i.e. total and population shares of catholics, protestants, jews and military) (1905) as Controls. Panel C includes geography (Pfalz), administrative independence (1896), population (total and religious shares) (1905), schools (1871, 1884 and/or 1906) and advocacy groups (1872) as Controls.

However, as outlined in section 3.3, simple OLS regressions based on the whole sample of counties may not be reliable since the opening of a modern secondary school in a county was driven by the endogenous factors. This implies that any estimation based on the whole sample is comparing completely different kinds of counties. Thus, the following two chapters approach this problem by sample restriction and differences-in-differences estimation.

### 4.3 Economic Effects using Restricted Samples

OLS results based on the restricted sample as outlined in section 3.3.1 are given in Table 9 for the Gewerbeschule and Table 10 for the Realschule. Note that these tables present economic effects of modern secondary education for comparable counties – based on propensity scores. Consequently, counties differ substantially only in terms of having opened a Gewerbeschule and/or Realschule or not.

**Table 9 - Economic Effect of the Gewerbeschule (Introduction by 1835), Restricted Sample**

Dependent Variable:	Number Self-Employed (1871) in		Number of Employees (1882) in		Average Number of
	Trade (1)	Industry (2)	Services (5)	Industry (6)	Net-Registrations (1869-1875) (7)
<b>Panel A: no controls</b>					
Gewerbeschule 1835	182.5** [67.08]	780.8** [314.5]	794.7*** [203.6]	3,538*** [1,208]	25.98*** [9.462]
<b>Panel B: small set of controls</b>					
Gewerbeschule 1835	36.47 [80.68]	353.8 [233.6]	8.636 [266.0]	1,364* [770.5]	11.30 [8.523]
<b>Panel C: large set of controls</b>					
Gewerbeschule 1835	27.92 [73.49]	180.1 [218.8]	116.1 [204.8]	1,716 [1,005]	15.03** [6.971]
Observations	34	34	34	34	34

Notes: Table reports OLS estimates. Unit of observation is a county. Robust standard errors are in parentheses: significantly different from 0 at \*\*\* 1%, \*\*5% and \*10% level. Sample includes observations with propensity scores  $0.01 < \text{score} < 0.9$ . Panel A includes no controls. Panel B includes geography (Pfalz), administrative independence (1871) and population structure (i.e. total and population shares of Catholics, Protestants, Jews and military) (1871 or 1880) as controls. Panel C includes geography (Pfalz), administrative independence (1871), population structure (1871 or 1880), traditional schools (1862) and advocacy groups (1872) as controls.

Results of Panel A in Table 9 are all positive and significant: counties that opened a Gewerbeschule in 1835 are associated with more people self-employed in trade and industry in 1871, more employees in services and industry in 1882 and a higher number of net registrations between 1869 and 1875 than comparable counties. Estimates in Panel B and C which are successively controlling for more (potentially endogenous) variables, are in most cases statistically insignificant; only the number of industrial employees in Panel B and the average number of business net registrations in Panel C are significantly and positively associated with having a Gewerbeschule. However, in contrast to the results in Table 7 (whole sample), all estimates are now positive.

**Table 10 - Economic Effect of the Realschule (Introduction by 1878 or 1896), Restricted Sample**

Dependent Variable:	Number of Businesses (1907) in				Number of Employees (1907) in		Average
	Trade	Industry	Chemical Indus.	Machinery	Trade	Industry	Number of new Patents (1902-1913)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
<b>Panel A: no controls</b>							
Realschule 1878	500.7*	727.2**	4.528***	25.61*	1,109**	4,780**	0.259**
	[277.8]	[336.7]	[1.684]	[14.28]	[434.1]	[2,008]	[0.104]
Realschule 1896	403.1	1,277	6.861	38.86	798.2	4,607	0.162
	[318.9]	[779.8]	[5.181]	[32.85]	[617.5]	[3,259]	[0.114]
<b>Panel B: small set of controls</b>							
Realschule 1878	-146.0	-51.36	0.524	-10.14	282.8	899.9	0.165
	[103.9]	[168.9]	[2.035]	[10.15]	[294.7]	[900.9]	[0.109]
Realschule 1896	2.350	779.6	4.011	13.56	298.6	2,176	0.127
	[207.7]	[521.7]	[4.363]	[23.88]	[441.5]	[1,980]	[0.103]
<b>Panel C: large set of controls</b>							
Realschule 1878	-204.3	-240.9	-1.417	-31.76*	-104.7	-693.5	0.0917
	[192.7]	[259.9]	[3.918]	[16.19]	[368.7]	[1,337]	[0.0844]
Realschule 1896	88.63	804.1	3.770	30.93	339.9	1,706	0.0378
	[249.0]	[522.0]	[5.790]	[26.78]	[522.8]	[2,042]	[0.0840]
Observations	54	54	54	54	54	54	54

Notes: Table reports OLS estimates. Unit of observation is a county. Robust standard errors are in parentheses: significantly different from 0 at \*\*\*1%, \*\*5% and \*10% level. Sample includes all observations with propensity scores  $0 < \text{pscore} < 0.9$ . Panel A includes no controls. Panel B includes geography (Bavarian Palatine), administrative independence (1896), population (i.e. total and population shares of Catholics, Protestants, Jews and military) (1905) as Controls. Panel C includes geography, administrative independence (1896), population (total and religious shares) (1905), schools (1871, 1884 and/or 1906) and advocacy groups (1872) as Controls.

The first and second row in each panel in Table 10 presents the estimates of the economic effect of having opened a Realschule in 1878 and 1896, respectively. Results in Panel A are all positive and significant: having had a Realschule since 1878 is significantly positively associated with the number of businesses in trade, industry, chemical industry and machinery, the number of people employed in industry and trade as well as with the average number of newly granted patents. Successively adding controls to the sample reveals that only counties which opened a Realschule relatively late – between 1878 and 1896 – are associated throughout with positive effects (although insignificant). For example, counties that opened a Realschule until 1896 are associated with 834 more industrial businesses in 1907. In contrast to the results obtained by the whole sample in Table 8, restricting the sample via propensity scores tangentially leads to more positive – although in most cases insignificant – positive effects.

According to these findings, counties that opened a Realschule later (by 1896) seem to have benefitted more from having modern secondary education than counties that opened a

Realschule in the year it was introduced (1878). A possible explanation for this finding could be that since these counties were on average less developed (as indicated by their propensity scores), they presumably benefitted even more from modern secondary education.

**4.4 Economic Effects obtained by Differences-in-Differences Estimation**

Table 11 presents differences-in-differences estimates capturing the effect of the introduction of a Realschule on the change in business net registrations. As in the previous regressions, Panel A includes no controls, Panel B includes population structure (total population plus shares of religious affiliations) and Panel C further includes traditional schooling (i.e. Gymnasium). The Realschule estimate is positive and significant only in Panel A: counties that opened a Realschule between 1877 and 1896 experienced an increase of 18.32 more average net registrations in the years between 1903 and 1907 than between 1873 and 1876 compared to counties that did not open a Realschule. However, as more control variables are included, the positive significant effect becomes negative.

**Table 11 – Differences-in-Differences Estimates of the Effect of a Realschule opening between 1877 and 1896**

Dependent Variable:	<u>Average Number of Net Registrations</u>
<b>Panel A: no controls</b>	
Realschule	18.32** [8.426]
<b>Panel B: small set of controls</b>	
Realschule	-8.641* [4.843]
<b>Panel C: large set of controls</b>	
Realschule	-8.789* [4.854]
Observations	290
Groups	145

Notes: Table reports OLS estimates using a differences-in-differences estimation including county fixed effects. Unit of observation is a county. Standard errors are in parentheses: significantly different from 0 at \*\*\*1%, \*\*5% and \*10% level. Panel A includes no controls. Panel B includes administrative independence and population as controls. Panel C includes administrative independence, population and Gymnasium as controls.

## 5 Conclusion

This paper analyzes the role of secondary education in economic growth, thereby focusing on innovations in the Bavarian schooling system during the 19<sup>th</sup> century. The introduction of the Gewerbeschule in 1829 and the Realschule in 1877 provide a unique opportunity to study this question in a historical context: polytechnic advocacy groups and the mercantile middle class lobbied for the introduction of these schools claiming that the humanistic Gymnasium could not offer an education preparing for commercial and industrial occupations. The Gewerbeschule and later the Realschule were supposed to meet this demand by offering scientific-technical as well as general education.

Since the curricula of these schools focused on subjects training commercial and industrial skills, the empirical analysis employs county-level data on business formations and people employed in trade and industry as well as the number of newly granted patents. Counties with are then compared to counties without modern secondary education in respect to these outcome measures capturing economic performance. Results obtained by OLS indicate that the opening of a Gewerbeschule in a county by 1835 is significantly associated with more people self-employed in industry in 1871. Restricting the samples to observations that are comparable in terms of their corresponding propensity scores, suggests that both the Gewerbeschule and Realschule are correlated with subsequent economic growth (although mostly insignificantly) – although, in case of the Realschule, most positive effects are restricted to late adopters. In a further approach to deal with the endogenous introduction of modern secondary schooling, the adopted differences-in-differences estimation yields significant positive results of the Realschule only for a parsimonious panel including no control variables.

Even though the empirical analysis is not able to find consistent significant positive effects of modern secondary education on economic outcomes, it can still be supposed that these schools actually contributed to growth. The work of Ringer (1979) – showing that graduates of modern education in Prussia intended to seek positions in industry and commerce – indicates that modern secondary education encouraged young people to enter these specific sectors and thereby contribute to economic prosperity. Furthermore, since there is no possi-

bility to control for migration of students and graduates, it could well be that the economic effect of modern secondary education would suffer from brain drain: if ambitious children (e.g. Rudolf Diesel) moved to counties in order to attend a Gewerbeschule or Realschule and after graduation migrated to less developed areas to realize economic opportunities which only exist because these counties are underdeveloped, these students would not have a positive economic influence on the county where the school is located.

Besides effects on the economy, modern secondary education might as well affect social mobility. As the Gymnasium understood itself as an institution for the elite (i.e. state officials, academics, physicians etc.) (BSKB XXVII, LII; ZKBSB 26, 38), the introduction of the Gewerbeschule and Realschule might have encouraged other social classes to participate in secondary schooling. The impact of modern secondary education on social mobility provides an interesting field for future research.

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