Project Report for Data Literacy 2023/24
Grade Inflation in the German School System - Causes and Effects

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Abstract

The reasons for the increase in Abitur grades have been a highly discussed topic in German society. Often, the reason for this is attributed to grade inflation. In this paper, we will show why this is not the case. Student competence has increased. One of the most important factors is the student-teacher ratio. We will show that this metric has a high correlation with the Abitur grades.

1. Introduction

The Abitur grades have constantly increased in the German school system over the past years (Kultusminister Konferenz), resulting in a research discussion in the media (todo source). The main topic of discussion is whether grades get better, even if students performance is worse.

The discourse has predominantly centered around mathematics, since the difficulty of exercises is easiest to compare. On the one hand-side, mathematicians argue that Germany has a grade inflation, resulting in easier exercises over the years (Kühnel, 2015; Jahnke et al., 2014; Lemmermeyer et al.). On the other hand-side, there are studies claiming that grade inflation cannot be reliably proven since the competence of students has also increased (Schleithoff, 2015). In 2015, a data-driven approach was employed by Grözinger & Baillet, involving the analysis of comprehensive data on the education system. The results were promising, but not yet enough to dismiss the claim of grade inflation.

This paper expands on that work, attempting to disprove the claim that grade inflation is the only cause of the observed trend. Building upon past research, a data analysis is conducted that aims to provide insight into the causes and effects on the schoolchildren's performance. [1].

Furthermore, this study investigates whether there are any quantifiable causes of this upward trend in Abitur grades in the German education system. In addition, the causes and evolution of the repeater ratio across all school types are investigated to project the results to other educational institutions. Finally, prognoses about the trajectory of future grade developments and their implications for the German education system are outlined.

2. Methods

The basis of the exploratory data analysis are the used datasets and the applied mathematical concepts for forming a quantitative argumentation. Thus, this section first introduces the used data sets and explains afterward the mathematical background. Finally, this section analyzes first trends and findings on the effects of increasing grades.

2.1. Datasets

This paper investigates both the causes and effects of the phenomena discussed in section 1. Thus, the analyzed datasets are grouped into *cause* and *effect* datasets. All used datasets are collected on all public schools, since they are obliged to forward the federal statistical institutions (Statistische Bundesamt, 2024; Kultusminister Konferenz).

In the following, *causes* are defined as the social, demographic, or political factors that influence the German school system, such as the number of students, teachers, or budget provided by the German government. In contrast, *effect* refers to the observable impact of these causes on any measure modeling the students' performance, e.g., average grades or the rate of repeaters and school-leavers.

The first dataset is the *Fachreport Schuljahr 2020/21* presenting the number of teachers from 1992 until 2020 (Statistische Bundesamt, 2022). The dataset is grouped into contract type, federal state, and school type. In addition, the count of schoolchildren is analyzed with two datasets (Statistische Bundesamt, 2024). The first dataset (21111−0002) contains

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[1]Source files are publicly available in the project repository.

the number of children per grade and school type for the years 1998 to 2022. In contrast, the second (21111 − 0010) provides the absolute number of children, leavers, and beginners in each federal state from 1997 to 2022. Therefore, the analysis can only be conducted separately for school types and federal states, due to the missing representation.

Additionally, this paper considers the budget per child (21711 − 0011) as a possible cause, which is provided by the Statistische Bundesamt. The dataset contains the budget per child for the years 2010 to 2022 and is grouped by federal states. To adjust for inflation, the budget is multiplied with the *Verbraucherpreisindex* (61111 − 0010) relative to 2022, as provided by the Statistische Bundesamt.

It is also important to analyze the effects on student performance, since they are the first indicator of whether grade inflation exists. One of the few publicly available datasets containing grades is the average Abitur grades per federal state. The grades are published every year in a separate report by the Kultusminister Konferenz. Each file contains the count of children per written grade and federal state. The grades are given in increments of 0.1, with 4.0 being the worst and 1.0 being the best grade. The number of children who failed with a grade worse than 4.0 is aggregated in an additional column.

Although this is a great model for the performance of children attending grammar schools, a general performance measure for all school types is required to translate the results to all school types. Accordingly, this paper uses the number of repeaters (21111 − 0014) from the Statistische Bundesamt. There, the absolute count of repeaters by federal state, school type, and year is provided for the years 1998 to 2022.

2.2. Mathematical Concepts

The subsequent paragraph provides an overview of two concepts: linear regression and the Pearson correlation coefficient.

Firstly, linear regression is a statistical technique for modeling the relationship between a dependent variable and one or more independent variables (James et al., 2021). It seeks to fit a linear equation to the data that minimizes the discrepancy between observed and predicted values. This is done through least squares minimization, resulting in an equation of the form (James et al., 2021):

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_p X_p + \epsilon \qquad (1)$$

Finally, the Pearson correlation coefficient r, is a statistical measure used to assess the linear relationship between two sets of data, X and Y (Rodgers & Nicewander, 1988). It is computed as the ratio of the sample covariance of X and Y to the product of their sample standard deviations (Rodgers & Nicewander, 1988):

$$r = \frac{\sum_{i=1}^{n}(X_i - \overline{X})(Y_i - \overline{Y})}{\sqrt{\sum_{i=1}^{n}(X_i - \overline{X})^2 \cdot \sum_{i=1}^{n}(Y_i - \overline{Y})^2}} \qquad (2)$$

2.3. Exploratory Data Analysis

Having introduced all used datasets, this paragraph aims to investigate potential patterns through an exploratory data analysis of the potential *causes* and *effects*.

Firstly, regard the demographic effects on the number of children attending school and teachers employed by school type and federal state. The exploratory data analysis has shown that the number of schoolchildren decreases steadily from 1998 to 2014. Instead, it increased from 2019 to 2022 because more children started their education and fewer left school. Furthermore, more children graduate from grammar schools with university entrance qualifications. This demographic effect is combined with an increasing number of teachers across all German school types and federal states. Although, the percentage of part-time teachers is increasing, the number of full-time teachers is decreasing until 2020.

Given the hypothesis that having more teachers per student increases the quality of teaching, the datasets can be merged. As already explained, this merge can only been done separately for school types and federal states. Furthermore, the student-to-teacher ratio is calculated over all full- and part-time teachers, since they represent the majority ($\sim 90\%$) of the distribution. In contrast, the teachers who are employed on an hourly basis are excluded due to their small impact on the teaching quality and sparse representation in the data. The results (Figure 1) show that from 1998 to 2020, the ratio decreased for the five most common school types. As a result, the average decreases from 29 to 24 children per teacher. Together with the hypothesis, it follows that the quality of teaching should increase, and thus the performance measures should increase.

Besides the demographic measures, the analysis of the adjusted budget to inflation per child has shown that it steadily increases for all federal states. Although, this may be caused by the increasing number of teachers and the goals of digitalization of schools in the last years (Cone et al., 2022).

Now that some basic effects that may influence the students' performance have been identified, it is possible to study the performance measures. As the analysis of the students datasets has shown, more children are attending grammar schools in Germany. Thus, the average Abitur grade of the children is a great measure of the performance of many children. Figure 2 shows that the average grades are increasing in all federal states. Furthermore, a linear regression can be employed to represent their mean. Importantly, the regression is calculated on the data before 2021 because of

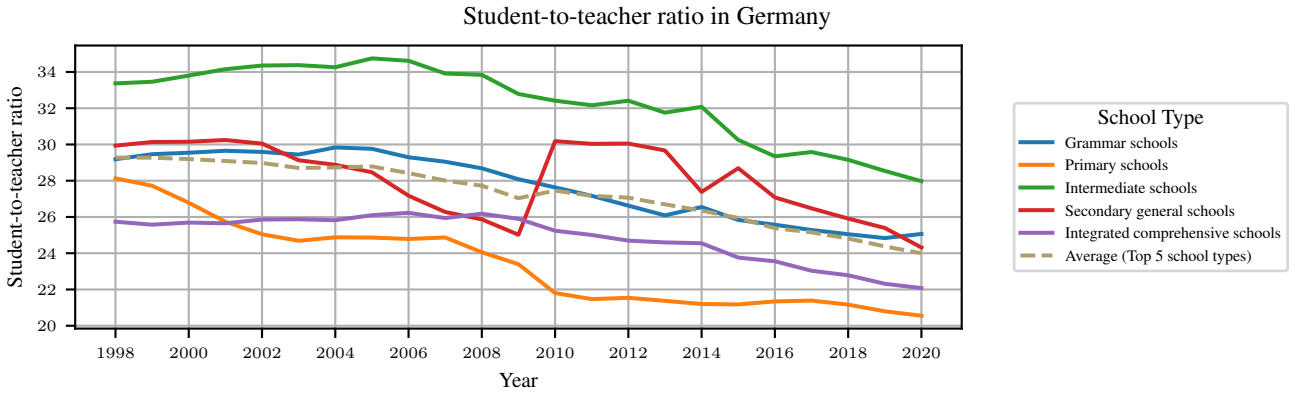

Figure 1. Students-to-teacher ratio of the five most common school types in Germany. The ratio of full- and part-time teachers is displayed for each school type and aggregated to their average (▬).

the COVID-19 pandemic beginning in 2020. In 2022, the grades significantly increased compared to the years before the pandemic. This could indicate that the pandemic has had novel consequences for the educational system. Due to the lack of data following the pandemic, this paper will solely focus on the linear trend until 2020. Furthermore, an additional analysis of the relative number of failed students has shown that the failure rate has no repetitive or linear pattern. Therefore, the provided results in Figure 2 are only valid for children graduating with a grade of at least 4.0.

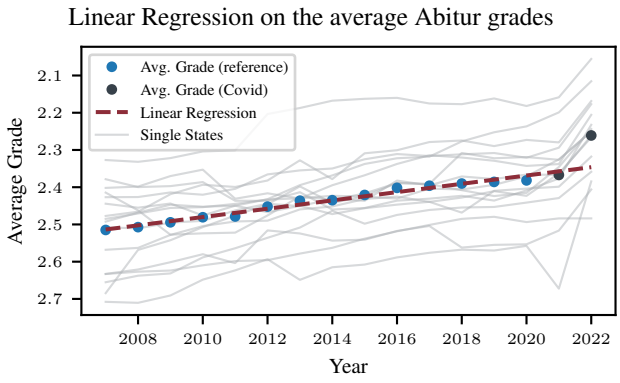

Figure 2. Average Abitur grades before (●) and after the COVID-19 pandemic (●) with a linear regression line (▬) of the years 2007 to 2020. In the background the figure contains average grades foreach federal state (_).

Moreover, all children attending other schools have no direct impact on the results of the Abitur grades. Therefore, the number of repeaters per federal state, school type, grade, and school year is analyzed. To enhance the relevance of the results, the relative ratio of repeaters is calculated by dividing the absolute counts by the absolute number of schoolchildren. This results in an aggregation for the federal states per year and in one for the school types per year. As a result, the number of repeaters has decreased for all educational institutions and federal states from 1998 to 2020. Hence, the trend equals the expected result, after analyzing the Abitur grades.

To summarize, the exploratory findings indicate an increasing number of students and teachers, resulting in a decreasing ratio of students to teachers and a rise in the budget per child. The possible outcomes include a linear increase in Abitur grades in grammar schools and a shrinking proportion of repeaters in general.

3. Results

The most intriguing discovery in our analysis is the robust correlation observed between the student-teacher ratio and Abitur grades. While it may seem intuitive, the data provides concrete evidence of the strength of the correlation. Initially, the average grades across all federal states are calculated and then compared to the student-to-teacher coefficient for German grammar schools.

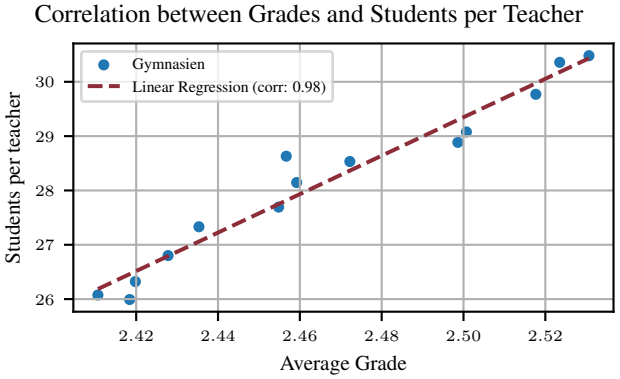

Figure 3. Linear regression on the students-to-teacher ratio by average Abitur grade. The resulting regression line (▬) is calculated over the aggregated average overall grammar schools (●) in Germany.

As shown in Figure 3, the relationship between both is nearly linear. In addition, the result contains neither clusters nor outliers. Hence, a smaller student-to-teacher ratio strongly correlates (Pearson correlation value of 0.98) with better Abitur grades. The association between student performance and the presence of teaching personnel is a familiar topic in research, often examined in the realm of university performance (Dickson, 1984). However, its application to this specific problem is novel, and the interpretation in this context is important. Since the student-teacher ratio got smaller in recent years and the grades went on a steep increase, this observation and the strong correlation underline the necessity of having enough teaching personnel available.

Figure 4 presents a visualization of the Pearson correlation coefficients, analyzing the relationship between the number of children per teacher and the average number of repeaters, as well as the educational budget per child. To visually represent the data across various federal states, a heatmap is generated. Therefore, the Pearson correlation coefficients for each state are normalised to the used colour map scale. Consequently, each state is assigned a colour, representing the correlation coefficient.

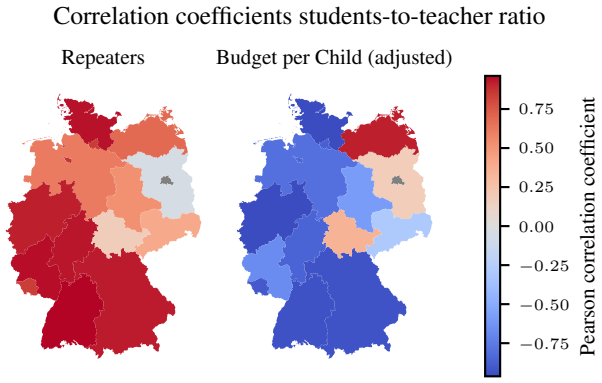

Figure 4. Pearson correlation coefficients between the student-to-teacher ratio and the relative repeater count (left) and the inflation-adjusted average budget per child (right). Red indicates positive, gray neutral, and blue negative correlations between the variables.

For most federal states, there is a strong positive correlation between the student-to-teacher ratio and the number of repeaters. Moreover, the correlation between the student-to-teacher ratio and the inflation-adjusted budget per child tends to be positive. Brandenburg and Thüringen are the exception in both cases, as they even have a slight correlation the other way around. For Mecklenburg Vorpommern, the correlation between student-teacher ratio and budget is also positive.

After seeing this visualisation, suggesting that schools simply require additional funding to hire more teachers might seem like a straightforward solution. The data from Thüringen, Mecklenburg-Vorpommern, and Brandenburg shows that this is not the case. For them, the correlation between budget and students per teacher is positive. These states have had an increase in the number of students over the past decade (Thüringer Ministerium für Bildung, Jugend und Sport, 2023; Brandenburger Ministerium für Bildung, Jugend und Sport, 2023; Statistisches Amt Mecklenburg-Vorpommern). If certain schools have more children, they might want to employ more teachers. This does not happen since they don't have enough teachers in these states available (Kultusminister Konferenz, 2023). This leads to schools getting more money, but the number of teachers staying the same or even decreasing because people retire. This leads to a negative correlation.

The same anomaly can be observed with the repeaters. Here, a different phenomenon is accountable for this. Schools in Thüringen and Brandenburg rely more and more on Teilzeitkräfte (QUELLE?). This means that the overall proportion of teachers increases, but since they only account for about half the teaching time, the number of children failing a class still increases.

For every other of the 16 federal states, there is a very strong positive correlation, not only for the Abitur grades but also for the number of repeaters. This can be interpreted as meaning that the sufficient availability of teachers not only increases grades but is especially beneficial for challenged students. A higher budget only helps when the schools can find teachers to employ. Making sure that many teachers are available is one of the most important challenges for the education system. The prognosis of the Kultusministerkonferenz (Kultusminister Konferenz, 2023) shows that there are still more open positions than teachers that can fill them. Unfortunately, they predict that this gap will eventually close in the coming decade. This means that a further increase in grades in the future can be expected.

It is important to note that having enough teachers is not the only factor responsible for the rising Abitur grades. Nonetheless, it is one of the most important ones. While the German education system faces several challenges, our demonstration illustrates that it has effectively addressed certain issues over the past decade and is poised to continue resolving them in the future. The increasing grades are a result of an increase in the competence of the students, facilitated by an improvement in the education system, especially a decrease in the student-teacher ratio.

4. Conclusion

We have introduced a new approach to explaining the increasing Abitur grades. There is a very strong correlation between the student-teacher ratio and the Abitur grades. Additionally, we also found a negative correlation between this

ratio and the repeater number. This means that the number of teachers not only has a positive impact on the grades but also on the more challenged students. Improving the budget does not necessarily help. It is essential for the German education system to have enough teachers available.

Grade inflation in the Abitur grades has not been scientifically proven so far. What has been proven is that student competence is increasing. It is important to acknowledge that the student-teacher ratio is not the only factor at play in improving education and, thus, student competence. Multiple factors are at play; some are already known through research, and some still need to be discovered. We have shown that the student-teacher ratio is a crucial one.

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