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De-tracking at the margin: How alternative secondary education pathways affect student attainment☆

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ABSTRACT

This paper estimates how marginal increases in the flexibility of between-school tracking affect student attainment by exploiting the addition of non-selective 'comprehensive schools' and hybrid 'vocational high schools' to Germany's tracked school system. These schools opened up alternative pathways to the university-entrance certificate, which traditionally could only be obtained at academic-track schools. We use administrative records to compile a county-level panel of school supply and attainment for 13 cohorts between 1995 and 2007. Cross-sectionally, the supplies of all three school types awarding the university-entrance certificate correlate positively with its attainment. However, for academic-track and comprehensive schools this association is not robust to the inclusion of regional controls, suggesting that it reflects regional differences in educational demand rather than supply-side effects. For vocational high schools, in contrast, we find robust evidence for positive attainment effects not only in cross-sectional and two-way fixed-effects panel regressions, but also in an event-study design that exploits the quasi-random timing of new school openings. Likely reasons for their success are that they lower the (perceived) costs of educational upgrading for late-bloomers, and their hybrid curriculum, which may retain students in general schooling who would otherwise enter vocational training.

1. Introduction

Across high-income countries, skill premiums have risen during the past sixty years despite rapid simultaneous educational expansion, indicating ever increasing demand for high-skilled workers (e.g., Becker & Blossfeld, 2022; Goldin & Katz, 2010). Increased skill demands in labor markets can be explained by shifts in industrial and occupational structure that result from globalization and routine-biased technological change: industries that traditionally employed high shares of low-skilled workers have declined, and routine tasks traditionally performed by low- but also middle-skilled workers, such as vocational education graduates, have been substituted by machines (e.g., Acemoglu & Autor, 2011; Dauth et al., 2021; Oesch, 2013). These developments mean that attainment of advanced academic credentials, such as university degrees, is ever more important for individual economic success, as well as for securing the economy's overall competitiveness.[1] Consequently, education systems face increasing pressure to 'produce' high-skilled graduates.

Yet, most education systems were set up in times with much lower skill demands and exhibit features that might stand in the way of educational expansion. In particular, many European school systems track pupils by ability between different school types from young ages onwards. The idea of tracking is to create homogeneous learning environments that allow for better-targeted, and hence more efficient, instruction. In most between-school tracked school systems there is

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[1] Further, educational expansion can itself fuel a cycle of credential inflation (Berg, 1971), where employers demand increasingly high qualifications, so that job seekers pursue more and more education to secure their position in the labor queue (Thurow, 1975).

[2] For example, the 'grammar school' in the UK, *VWO* in the Netherlands and *Gymnasium* in German-speaking countries.

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a designated high (or 'academic') track, originally intended for only a small minority of high-achieving students.[2] Typically, only graduation from this high track grants access to university, while the lower tracks channel the majority of students into upper-secondary vocational education and training (VET).

Despite its goal of enhancing efficiency, both *ability tracking* between different (lower-secondary) school types and *curricular tracking* between (upper-secondary) vocational and academic education have been criticized as obstacles to higher education expansion: the former puts many students on a non-university-bound pathway early on, even though some of them may have attained higher degrees had they been exposed to higher-achieving school environments for longer, while the latter may divert many students away from university-bound academic education into VET (e.g., Powell & Solga, 2011). Especially students from lower socioeconomic backgrounds might be held back through both of these mechanisms (e.g., Bauer & Riphahn, 2006; Birkelund & van de Werfhorst, 2022; Borghans et al., 2020; Brunello & Checchi, 2007; Kerr et al., 2013; Meghir & Palme, 2005).

In response to these arguments several European countries, such as England, Finland and Sweden, replaced their tracked school systems with comprehensive ones (at least for the lower secondary phase) during the 1960–70s. Others, such as Germany, Switzerland, and the Netherlands, have eschewed such structural de-tracking reforms until today. To still cater to increasing educational demand, most of them have instead gradually decreased the rigidity of their tracking systems by increasing the high track's capacity and/or track permeability in different ways, e.g., by introducing hybrid school types. Such incremental, or 'marginal', de-tracking reforms open up new educational pathways, but leave it up to students' (and their parents') choices whether these are actually used. This choice-based approach contrasts with the 'regulatory approach' of structural de-tracking reforms, which simply abolish tracks and hence impose uniformity in educational pathways top-down.

While structural de-tracking reforms have received a lot of attention in the empirical literature (e.g., Kerr et al., 2013; Malamud & Pop-Eleches, 2011; Meghir & Palme, 2005; Pekkarinen et al., 2009), the effects of marginal de-tracking are less well understood. Critics posit that, in light of the above arguments, marginal tweaks to the tracking system can achieve only little in terms of boosting attainment and reducing inequality as long as the early selection of students into different schools is retained. Proponents counter that such adjustments can be effective precisely because they retain the general efficiency benefits of tracking that stem from homogeneous schools for 'inframarginal' students, but lift the constraints tracking imposes on 'marginal' students, so that they can realize their full potential and attain higher certificates (Dustmann et al., 2017; Mühlenweg & Puhani, 2010).

In this paper we study the impact of marginal de-tracking on student attainment in Germany. The country's education system is often considered the prime example for rigid ability tracking between school types during the lower secondary phase, and curricular tracking between school-based academic education and firm-based apprenticeship training during the upper secondary phase. Indeed, despite a long-standing political debate on tracking, both of these institutions have proved remarkably stable over time (Ertl & Phillips, 2000; Neugebauer et al., 2013). Nevertheless, it would be wrong to speak of institutional stasis because, even though the core of the tracking system has been retained, several innovations were added to the existing school structure in a process that may be described as 'institutional layering' (Streeck & Thelen, 2005).

In addition to an expanding supply of academic-track schools (*Gymnasium*), two notable changes in this respect are the introduction and gradual expansion of two new school types, which were added to the schools of the traditional tracking system without replacing them: 'comprehensive schools' (*integrierte Gesamtschule*) and 'vocational high schools' (*berufliches Gymnasium/Fachgymnasium*). Both offer alternative pathways towards the upper-secondary university-entrance certificate (*Abitur*), which traditionally could only be obtained at academic-track schools. Hence, they constitute a partial de-tracking of upper-secondary schooling. However, they do so following two very different logics. Comprehensive schools—like academic-track schools—cover the entire secondary phase, i.e., both the lower-secondary (5–10) and the upper-secondary grades (11–13). Unlike academic-track schools, they are open to all students regardless of their performance in primary school. Only progression to the upper-secondary phase requires a certain grade point average (GPA). Accordingly, comprehensive schools offer an alternative to tracked secondary schooling. Vocational high schools, in contrast, cover only the upper-secondary grades and thus merely offer students who were initially not sorted into the academic track, the option to upgrade after completing one of the lower tracks. They also attenuate curricular tracking because, while they offer the academic upper-secondary curriculum and award the corresponding university-entrance certificate, they augment this with vocational content.

To empirically identify how comprehensive schools and vocational high schools affect student attainment we exploit that not all students in Germany have been equally exposed to these innovations. These school types were legally introduced at the state level but their actual provision was left to local authorities, resulting in large regional and temporal disparities in their availability (Helbig & Nikolai, 2015). Therefore, we take a regional approach and estimate, at the level of counties, how the local supplies of comprehensive schools and vocational high schools affect the local attainment rate of the university-entrance certificate (*Abitur*). To compare this with the impact of academic track capacity increases, we perform the same analysis for traditional academic-track schools.

Our analytical strategy proceeds in three steps, moving from mainly descriptive to plausibly causal. First, we model the county-level relation between attainment and school supply cross-sectionally, controlling for cohort fixed-effects, state fixed-effects, and a large array of county-level socio-economic characteristics, aimed at capturing the most important endogenous dynamics in the demand for education. Second, we turn to two-way fixed-effects (TWFE) regressions, which remove time-constant unobserved heterogeneity between counties by county fixed-effects. Third, we exploit the quasi-random timing and discrete nature of the introduction of new school types in counties where they were not previously available as 'natural experiments' in an event-study design.

We draw on regional administrative data sources covering school supply, student enrollment, and graduation counts for all German counties over the time frame 1995–2016, as the available survey data is not representative at low enough levels for our analysis. From this we compile a novel county-level panel of school supply and upper-secondary attainment for 13 cohorts entering secondary school between 1995 and 2007, by reconstructing the school mix locally available at the time of their primary–secondary transition and their *Abitur* attainment rate nine years later. We focus on attainment of the university-entrance certificate because it is well-comparable across Germany and arguably the country's most important educational certificate, not only determining access to higher education but also having become a *de facto* prerequisite for "higher-ranked vocational training opportunities, such as for bank clerks or information technology clerks" (Powell & Solga, 2011).

The data confirms the well known fact that average attainment is rising throughout our observation period. More notably, it reveals that cross-county differences in attainment are striking and increasing over time, suggesting growing regional educational inequality. Regional differences in school supply are equally large, yet somewhat more stable over time. However, especially vocational high schools have slowly but steadily expanded over the period considered.

Cross-sectionally, we find that the local supplies of all three school types with upper-secondary provision, i.e., academic-track schools, comprehensive schools, and vocational high schools, correlate positively with local *Abitur* attainment rates. However, for comprehensive and academic-track schools we fail to find convincing evidence that the supply-attainment correlations reflect causal supply-side effects, given that the cross-sectional estimates are sensitive to the inclusion of regional controls and that the longitudinal TWFE and event-study estimates fail to show significant effects.

For vocational high schools, in contrast, we find convincing evidence of a causal positive supply-side effect on attainment. Already the cross-sectional supply-attainment correlation is remarkably robust to controlling for various socio-demographic controls and state fixed-effects, as well as weighting for population size and aggregating to higher regional levels. The TWFE regressions show that, also within regions over time, the supply of vocational high school correlates positively with attainment. This effect is similarly robust to weighting, level of aggregation, sample restrictions, as well as to the inclusion of county-specific linear trends. Finally, the event-study reveals a sudden and significant increase in *Abitur* attainment in counties opening their first vocational high school, compared to counties that continue to have no such school. Importantly, it also shows that attainment trends between these two groups of counties are parallel until the vocational high school introduction, suggesting that the exact timing of these events is indeed quasi-random.

Our event-study estimates suggest that, at the extensive margin, the introduction of a single vocational high school, when it was not previously available in a county, increases *Abitur* attainment rates by about 2.4 percentage points (pp) over a baseline of 30 percent. The TWFE regression suggest that, across extensive and intensive margins, a supply increase of one school per 1000 students, which corresponds roughly to one standard deviation in the cross-section and to about one slot per 100 students, increases attainment rates by about 1.5 pp on average. As these schools have become widespread (at the end of our observation period 78% of counties have at least one vocational high school and the average is one school per 1000 students), they have substantially contributed to upper-secondary educational expansion in Germany.

The contribution of this paper is twofold. First, we contribute to the literature on educational tracking, which has largely relied on cross-country comparisons between tracked and comprehensive school systems (e.g., Brunello & Checchi, 2007; Hanushek & Woessmann, 2006; Pfeffer, 2008; van de Werfhorst, 2019; Waldinger, 2007) or analyzed a single country's structural de-tracking reform (e.g., Brunello & Checchi, 2007; Kerr et al., 2013; Malamud & Pop-Eleches, 2011; Meghir & Palme, 2005; Pekkarinen et al., 2009). Yet, not only are country-level comparisons prone to suffer from omitted variable bias, by categorizing school systems into one of two broad categories they might also miss subtle but important forms of institutional stratification at the subnational or school level. Similarly, structural de-tracking reforms might provide a credible source of identifying variation but they tell us little about how marginal increases in the flexibility of tracking systems, which are observed in most countries that have retained their between-school tracking systems, have impacted attainment. We contribute by analyzing an incremental and regionally decentralized de-tracking process in a system that is formally still strictly tracked, focusing its impact on attainment.

We find mixed results regarding the effects of introducing non-traditional pathways towards university eligibility. On the one hand, comprehensive schools do little to raise attainment at the top. We hypothesize that is because academic-track schools continue to cream-skim the best students at the end of primary school, so that comprehensive schools do not provide substantially higher-achieving peer environments than intermediate- or low-track schools (Puhani & Weber, 2007). Given the choice, the preferences of higher-achieving students' not to study with lower-achieving peers seems to prevail in enforcing a tracked equilibrium. Accordingly, despite their name, comprehensive schools fail to deliver a truly *comprehensive* schooling alternative within an otherwise tracked system.

On the other hand, the *upgrading* model that vocational high schools provide, appears quite effective in raising upper-secondary attainment. The effect is similar to that of a major school reform in Sweden that completely de-tracked lower-secondary schooling, which increased upper-secondary attendance by 2.6 pp (Meghir & Palme, 2005). We argue that this is because vocational high schools complement the tracking system by offering a second chance after the initial placement, instead of attempting to challenge it from the start like comprehensive schools. They reduce the costs of upgrading for non-academic-track students whose scholastic potential is revealed only later, but who might be hesitant to upgrade to traditional academic-track schools given their elitist aura and already established peer groups. This confirms prior research which highlights the importance of second-chance option for late bloomers in tracked systems (Mühlenweg & Puhani, 2010). Further, because these schools combine academic and vocational curricula, they might also be attractive to risk-averse students who, in the traditional system, would have been diverted towards VET.

Second, and more generally, our findings speak to the literatures on school supply and school choice as sources of spatial inequality of opportunity. The place where individuals grow up profoundly shapes their life chances (e.g., Chetty & Hendren, 2018; Durlauf, 2004). In line with the studies on school openings (e.g., Duflo, 2001; Filmer, 2007) and on college proximity (e.g., Card, 1993; Gibbons & Vignoles, 2012; Spiess & Wrohlich, 2010), we investigate whether such neighborhood effects are mediated by the types of secondary schools locally available. In the context of Germany's tracked school system, we find that the availability of vocational high schools indeed induces a group of marginal students complete academic upper-secondary schooling who would not otherwise. Accordingly, the differential supply of these schools contributes to regional differences in attainment. That the local mix of schools affects track choices confirms previous results for France (Garrouste & Zaiem, 2020) and England (Dickerson & McIntosh, 2013). At the same time, our results regarding comprehensive schools suggest that families' tendency to exercise school (type) choice to maintain differentiation limits the potential of school supply focused policies to reduce inequality.

The paper proceeds as follows: Section 2 describes the institutional background in more detail. Section 3 describes the construction of the data. Section 4 presents our empirical strategy. Section 5 presents the results. Finally, Section 6 discusses implications and concludes.

2. Institutional background

In Germany sovereignty over education policy lies with the state governments. The states coordinate on common standards, e.g. regarding degrees and admissible school types, but retain autonomy over the actual design and implementation of policies. Within this unique situation of educational federalism, a school system has developed that is fairly homogeneous across Germany in terms of basic structure, teaching methods, and curricula, but exhibits fine differences within some areas of schooling policy—especially school structure and thus tracking practices.

Throughout Germany, students attend four years of comprehensive primary school before they are tracked into different school types by their previous performance (at about age ten).[3] Traditionally, there were three secondary school types that corresponded to distinct educational tracks and led to different school-leaving certificates: the academic track (*Gymnasium*), lasting nine years and preparing for university; the intermediate track (*Realschule*), lasting six years and preparing for higher-level VET; and the low track (*Hauptschule*), lasting five years and preparing for lower-level VET. Only academic-track schools used to award the university-entrance certificate (*Abitur*).

Over the past decades, the school system underwent several changes in all states. However, the early selection of students between the academic and lower tracks has not been challenged. Changes concern the

[3] Except for three states (Berlin, Mecklenburg-Vorpommern, and Brandenburg) where primary school lasts six years.

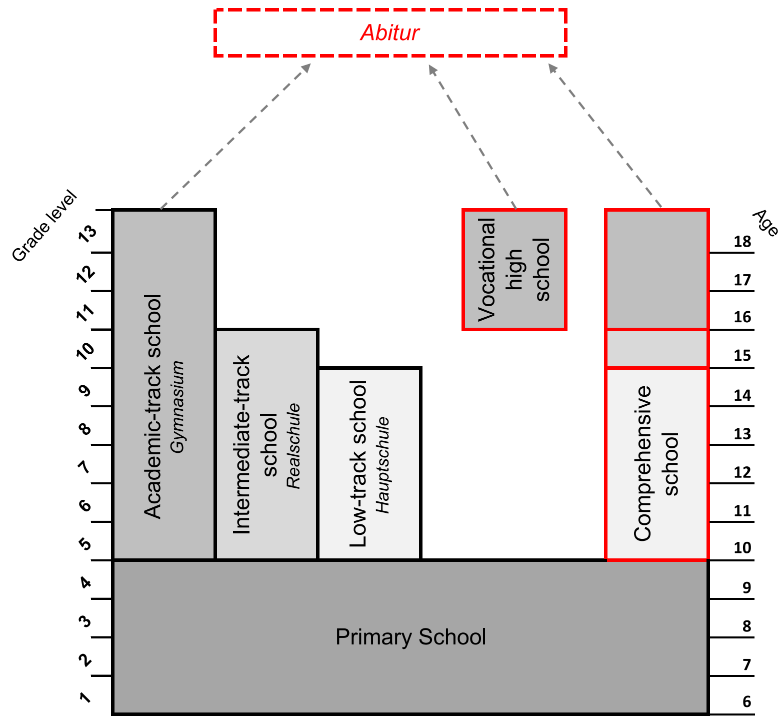

Fig. 1. Traditional and alternative pathways to the *Abitur*.

allocation of students across tracks and the nature of the corresponding school types. Regarding the former, many states abandoned the binding nature of track recommendations (Dollmann, 2016; Neugebauer, 2010) and enhanced track permeability (Buchholz & Schier, 2015; Schindler, 2015, 2017). Regarding the latter, several states merged the lower two tracks into one (Matthewes, 2021; Neumann et al., 2013) and most states added two new school types, which are the focus of this paper: comprehensive schools and vocational high schools. In contrast to the other reforms, these two new school types add new choice options for students instead of altering the rules of tracking. Both of them award the *Abitur* certificate and thus offer an alternative pathway towards university eligibility. They do so quite differently, however: comprehensive schools—like traditional academic-track schools—cover all secondary grades (5–13), whereas vocational high schools only cover the upper-secondary grades (11–13).

Fig. 1 summarizes the structure of the German tracking system, highlighting the three possible pathways to *Abitur* attainment via traditional academic-track schools and the newer comprehensive schools and vocational high schools.[4] While academic-track schools remain by far the most common route towards the *Abitur*, comprehensive and vocational high schools make up for an important portion of students who reach this qualification (9% and 14% of graduates in 2018, respectively).[5] Importantly, the legal value of the *Abitur* is independent of where it was obtained, and universities may not discriminate based on the school type of applicants.

Comprehensive schools were first introduced around 1970 by Berlin, North Rhine-Westphalia, and Lower Saxony as pilots with the aim of detracking secondary schooling altogether (Köller, 2008). However, due to opposition from the public, the full reform was never completed: comprehensive schools were eventually institutionalized, but without replacing the three traditional tracks, as originally intended. Over the decades that followed, most states added comprehensive schools, though the extent of their adoption varied (Helbig & Nikolai, 2015).[6] As of today, only Bavaria and Saxony do not have comprehensive schools.

Comprehensive schools are open to students of all abilities. They offer a general lower-secondary curriculum compatible both with continuing with VET and upper-secondary academic schooling.[7] For the former, students would leave school after grade 9 with a low certificate or after grade 10 with an intermediate one (after taking the respective final exam). For the latter, students need to obtain a sufficiently high GPA in grade 10, after which they can stay on until the end of grade 13 and take the *Abitur* exams.[8] Comprehensive schools typically have a more heterogeneous student body than traditional track-specific schools. However, as they coexist *next* to the tracked system, most high-achieving students still attend academic-track schools (Köller, 2008; Puhani & Weber, 2007).

The introduction of vocational high schools has been less controversial than that of comprehensive schools, but similarly gradual and geographically heterogeneous. Starting with Baden-Wurttemberg in the late 1960s, all states have now adopted this school type, though, again, the extent of adoption varies (Helbig & Nikolai, 2015). Bavaria is a special case because formally it never introduced vocational high

[4] In Online Appendix Table B1 we summarize the key characteristics of each school type.

[5] Source: Statistisches Bundesamt (2001a, 2001b).

[6] Since comprehensive schools are the product of historically stratified reforms, their names and specificities vary slightly across the country. They are variously known as *integrierte Gesamtschule*, *integrierte Sekundarschule* and *Gemeinschaftsschule*. We follow the defining approach of national statistics, by grouping together all lower-secondary schools (other than academic-track schools) that enable the pursuit of the *Abitur*. The schools we study are distinct from the *kooperative Gesamtschule*, which is simply a school building that hosts distinct tracks (partially overcoming the physical segregation of tracked students). For these schools, each track is counted as separate schools in the national statistics.

[7] Though note that, despite their name, most comprehensive schools do implement some form of ability grouping in core subjects from grade 7 onward (Köller, 2008).

[8] During the upper-secondary grades (11–13), comprehensive schools provide academic instruction either in-house or via cooperation agreements with other schools.

schools. Instead, it allowed an already existing vocational school type, *Fachoberschulen* (FOS), to add the final upper-secondary grade (13) and to award the *Abitur*. As FOS in Bavaria are functionally equivalent to vocational high schools elsewhere, we will not differentiate between them. We mention this detail here only because it has some implications for the event-study analysis.

Vocational high schools only cover the three upper-secondary grades, during which they offer the standard academic curriculum in core subjects, but replace some secondary subjects with vocational courses in a student-chosen field of specialization. The fields students can pick from are: business administration, technical studies, health and social care, agriculture, nutritional sciences, social pedagogics, and biotechnology.[9] Vocational high schools award three different certificates: (i) the standard *Abitur* (*allgemeine Hochschulreife*) which gives access to all university majors; (ii) a major-bound *Abitur* (*fachgebundene Hochschulreife*) which entitles for university but only in certain majors (and accordingly allows dropping certain subjects outside of that field in school); and (iii) a vocational certificate (*Fachhochschulreife*) which gives access to tertiary vocational education (in universities of applied science), takes only two years to complete (i.e., students would graduate after grade 12), and can also be attained in other vocational schools. Because our focus is on university eligibility, in the empirical analysis we focus on the first two certificates.

Because vocational high schools only cover upper-secondary schooling, students enroll in these schools after having completed lower-secondary schooling elsewhere. Admission requires the intermediate school-leaving certificate with a sufficiently high GPA.[10] The vast majority of enrollees attend lower-secondary schooling in an intermediate-track school and then directly enroll in vocational high school after their graduation in grade 10 (Winkler, 2017; Zimmermann, 2019). A small share of vocational high school enrollees are students switching from academic-track schools (e.g., because they seek the vocational specialization). In some cases, vocational high schools are also formally open to older individuals who undertook vocational training after completing lower-secondary school, but empirically this pathway is not common (Winkler, 2017; Zimmermann, 2019).[11]

Even though both new school types are legally introduced by state governments, their local availability depends on local authorities. Within states, counties (*Stadt-/Landkreise*) or municipalities (*Gemeinden*) are responsible for the administration, resource allocation, and capacity planning of schools.[12] For the latter, a designated committee within the county administration is tasked with 'school development planning' (*Schulentwicklungsplanung*), i.e., guaranteeing a sufficient number of school slots across school types. This implies decisions on the capacity of existing schools and on school closings and openings.[13] Therefore, at a given point in time, the availability of different school types does not only depend on the state a student lives in, but also on her location within that state.

Importantly for our identification strategy, local school development planning is a largely unpolitical, bureaucratic, and slow process: the county's or municipality's planning committee formulates long-term plans—typically covering ten years or more—based on the intersection between educational priorities set by the state government and local demographic forecasts, available transportation networks, and quantitative indicators of building and personnel capacities (Podewski, 2022; Terpoorten, 2022).[14] The school development plan eventually needs to be approved by the electoral body of the local district and the state's education ministry, but elected politicians are not involved in, nor oversee, its development. Therefore, although local political actors and stakeholders may try to influence this process (Bartl & Sackmann, 2016), their immediate impact is very limited (Zymek et al., 2011). In particular, the exact timing of school closings and openings, and hence variations in school supply occurring from one year to the next, are almost completely unpredictable for families. We exploit this feature of local school supply in our identification strategy.

3. Data

Our analysis is based on regional administrative records for the time frame 1995–2016 provided by the German federal states.[15] The raw data consists of secondary school type specific counts of schools, enrolled students, and *Abitur* graduates in a given year for a given region. The lowest level of regional aggregation available in the data—hence our primary regional unit of analysis—is the NUTS-3 level of counties (*Kreise*), of which there are 402 across Germany. Deciding on the level of regional aggregation involves a trade-off: lower levels of aggregation allow for a more granular depiction of regional differences and increase statistical power, but come at the cost of increased measurement error due to student mobility across regional borders. Therefore, we repeat all our analyses at the level of planning regions (*Raumordnungsregionen*), of which there are 96 across Germany and which thus represent a substantially higher level of regional aggregation.

Regardless of the chosen level of regional aggregation, we have to transform the raw region × year count data into a region × cohort dataset to relate local school supply with attainment rates. We define *secondary school entry* cohorts by the year students enter fifth grade, which corresponds to the first year of secondary school.[16]

Our main independent ('treatment') variables of interest are the local supplies of the three different school types with upper-secondary provision. We operationalize the supply of school type $j \in \{V, C, A\}$ (for vocational high schools, comprehensive schools, and academic-track schools, respectively) for entry cohort c from region i as the number of schools available in that region (per 1000 students) in the relevant year of transition, t_{icj}, which in the vast majority of cases equals the year of fifth grade entry, c, for comprehensive and academic-track schools and the year of eleventh grade entry, $(c+6)$, for vocational high schools[17]:

[9] Not all specializations are available at all schools. In fact, many vocational high schools specialize in one or two fields.

[10] The minimum GPA requirement vary between 2.5 and 3.0 across states (on a scale from 1.0, highest, to 6.0, lowest, where a 4.0 is required to pass).

[11] Other institutions like *Abendgymnasien* and *Kollegs* (the so-called 'second-chance' sector) are explicitly designed for non-linear pathways, allowing students to enter academic education after VET. See footnote 21.

[12] In some states, like Hesse and Thuringia, only counties function as school authorities (*Schulträger*), whereas in others, like Bavaria and Baden Wurttemberg, the majority of schools is run by lower-level municipalities (see Goertz & Hense, 2020, for an overview).

[13] For more information on school development planning, see: https://eurydice.eacea.ec.europa.eu/national-education-systems/germany/organisation-primary-education (accessed on: June 4, 2024).

[14] See this link for an example of a school development plan for the Bavarian county Starnberg: https://www.lk-starnberg.de/media/custom/613_20306_1.PDF?1347676299 (accessed on: June 4, 2024).

[15] These are partly available online and partly bought from the Statistical Offices of the Federal States. See Online Appendix A for details.

[16] In three states (Berlin, Mecklenburg-Vorpommern, and the excluded Brandenburg) the primary–secondary transition takes place two years later, i.e., after sixth grade. As grade repetitions spike in the year before the transition, we record the size of entry cohorts in seventh grade when all students have transitioned, by summing over the seventh-grade enrollment counts of all secondary school types.

[17] The time point of transition is a function of school type (j) because students enter comprehensive and academic-track schools directly after primary school, but vocational high school only after completing lower-secondary schooling (i.e., after grade 10). It is further a function of county (i) and cohort (c) because in a few states the transition from primary to secondary schools takes place after grade 6 instead of grade 4, as is the norm. The later transitioning states are Berlin and Brandenburg throughout our observation period and Bremen, Lower Saxony and Mecklenburg-Vorpommern for parts of our observation period.

$$S^j_{ic} = 1000 * \frac{N \text{ schools of type } j \text{ in region } i \text{ in year } t_{icj}}{\text{size of cohort } c \text{ in region } i}$$

The number of schools of each type is a rather crude measure of supply compared to the number of available slots which we would ideally use but do not observe. Importantly, however, it ensures that we measure school supply *net of demand*, whereas more granular enrollment counts constitute the equilibrium outcome between supply and demand for specific school types and are thus unsuited for an investigation of supply-side effects. In Online Appendix Figure B1 we compare the average size of the three school types: the median number of enrolled upper-secondary students per school per cohort is 71 for vocational, 65 for comprehensive, and 85 for academic-track schools, indicating that they are roughly comparable in the number of available slots per school.

Fig. 2 shows scatter plots for the three school supply variables at the county level. It reveals considerable regional variation in the types of schools available and that, even though clusters of states (colors) are clearly recognizable, a lot of this variation is within states. The between-county variation in roughly similar for comprehensive and vocational high schools. A high share of counties does not have either of the new school types, but this share decreases over time, mainly due to the introduction of vocational high schools whose supply is slowly increasing over time. Unfortunately for estimation, there is less over-time variation in the supply of comprehensive schools.

A pattern that jumps out in Fig. 2 particularly for academic-track schools (though it is visible for all three school types) is the sudden and stark increase in supply levels in East German states (depicted in brighter colors) starting in 2000.[18] This is due to a sudden drop in birth rates in Eastern Germany after reunification in 1990 ('*Geburtenknick*') causing decreases in secondary school entry cohort sizes from 2000 onward (as secondary school starts when students are 10 years old). Hence, these increases in supply are driven by falling student numbers (i.e., decreases in the denominator), rather than by the introduction of new schools (i.e., increases in the numerator) as in the vast majority of West German states. While part of this reflects actual increases in supply (i.e., an increase in the number of available slots per student), part of it is measurement error, as authorities reduced the number of available slots per school (and consolidated over the following years through school closures and mergers, as is visible from recovering supply levels both in this figure and in Online Appendix Figure B3). Accordingly, it is somewhat unclear in how far this variation is useful or harmful for our purposes. Consequently, we repeat all analyses excluding the East German states.

Our outcome of interest is the *Abitur* attainment rate, i.e., the share of a given cohort from a given region graduating high school with a university-entrance qualification.[19] As in the data we cannot follow individual students over time, we approximate the attainment rate of cohort c from region i by dividing the region's count of *Abitur* graduates in the year students from that cohort are *expected* to graduate, g_{icj}, by the cohort's size[20]:

$$Y_{ic} = \frac{\sum_{j\in\{V,C,A\}} \left(N \text{ Abitur graduates from school type } j \text{ in region } i \text{ in year } g_{icj}\right)}{\text{size of cohort } c \text{ in region } i}.$$

Accordingly, we introduce measurement error in our outcome variable to the extent that students do not graduate in the expected year (e.g., through grade repetition).[21] This first measurement problem is innocuous for identification as long as grade repetition is not systematically related to our measures of school supply, which we believe is a reasonable assumption.

A second measurement problem arises if students move to another region between lower- and upper-secondary school, because cohort size—the denominator of the outcome variable—is recorded when students are in lower-secondary school (in grade 7), but the number of graduates—the numerator of the outcome variable—is recorded at the end of upper-secondary school (after grade 12/13). Generally, students do not change school after their first secondary enrollment. Yet, 'upgrading' students, i.e., those who want to pursue *Abitur* but are enrolled in a school without upper-secondary provision, have to enroll in a new school after tenth grade. If they enroll in a different region for their upper-secondary education, we *underestimate* the graduation rate in the student's original ('sending') region and *overestimate* it in the final ('receiving') region because these students are counted toward the former's cohort size but the latter's graduates.[22] This is innocuous for identification if regional mobility is random. However, it is likely to correlate with our treatments because students from regions with low supply of upper-secondary schools are more likely to enroll in upper-secondary education in a neighboring region with a higher supply of these schools than *vice-versa*, potentially leading us to overstate the association between upper-secondary school supply and graduation rates. This is a particular concern for vocational high schools, which enroll all their students after tenth grade. As between-region mobility is less likely the higher the level of regional aggregation, it is thus key to probe the robustness of our estimates to different levels of aggregation. It should be noted that most counties have self-contained school systems, so that this problem should only be relevant for a small number of bordering rural and urban counties and virtually absent at the level of planning regions, which aggregate over cities and their sub-urban/rural surroundings.[23]

[18] This is even more apparent in Online Appendix Figure B3, which plots the evolution of all three school supply measures at the state level.

[19] Our definition includes the standard *Abitur* (*allgemeine Hochschulreife*) and its major-bound version (*fachgebundene Hochschulreife*). It excludes the certificate that only gives access to universities of applied science (*Fachhochschulreife*).

[20] The year of expected graduation is a function of region, cohort, and school type because of the so-called G8 reform, which was introduced by most states at some point during our observation period. The reform reduced the number of school years until *Abitur* graduation from 9 to 8 years *on academic-track schools only*: before introduction of the reform, the expected year of graduation equals $c + 9$ irrespective of school type. After introduction of the reform, the expected year of graduation equals $c+8$ for students on academic-track schools, but $c + 9$ for students on comprehensive and vocational high schools. We take the staggered introduction of the state-level reform into account when constructing attainment rates (which is possible because our graduation count data is school type-specific). Further, we include dummies for the final G9 cohort and the first G8 cohort in all our regressions to control for any influence the reform might have had on (the timing of) graduating. Information on state-specific reform timing comes from Marcus and Zambre (2019).

[21] One might particularly worry about non-standard school trajectories among graduates from vocational high schools (VocHS). VocHS are supposed to only enroll *Abitur*-bound students directly after they complete grade 10, not those who first do an apprenticeship before returning to school to complete *Abitur*. Such so-called 'second-chance' students are supposed to enroll in *Abendgymnasien* and *Kollegs* instead. Non-compliance with these recommendations means that (in some states) VocHS graduation counts might be inflated by second-chance graduates. Because these students are not directly identifiable, as a workaround, we scale down the count of *Abitur* graduates from VocHS by the state-specific share of VocHS students aged above 20 who are likely to be second-chance graduates, using the state-specific age distribution of VocHS enrollees retrieved from Statistisches Bundesamt (2001b). The mean of this share is 0.13 with a standard deviation of 0.07.

[22] If students enroll in a secondary school outside of their home region before grade 7 (e.g., with the start of secondary school) there is no measurement problem because cohort size and graduation counts would be recorded in the same region.

[23] The problem arises because large cities and their surrounding sub-urban/rural areas are generally classified as separate counties despite sometimes having non-negligible overlap in their school systems: for example, students from the suburbs might attend *lower*-secondary school in their rural

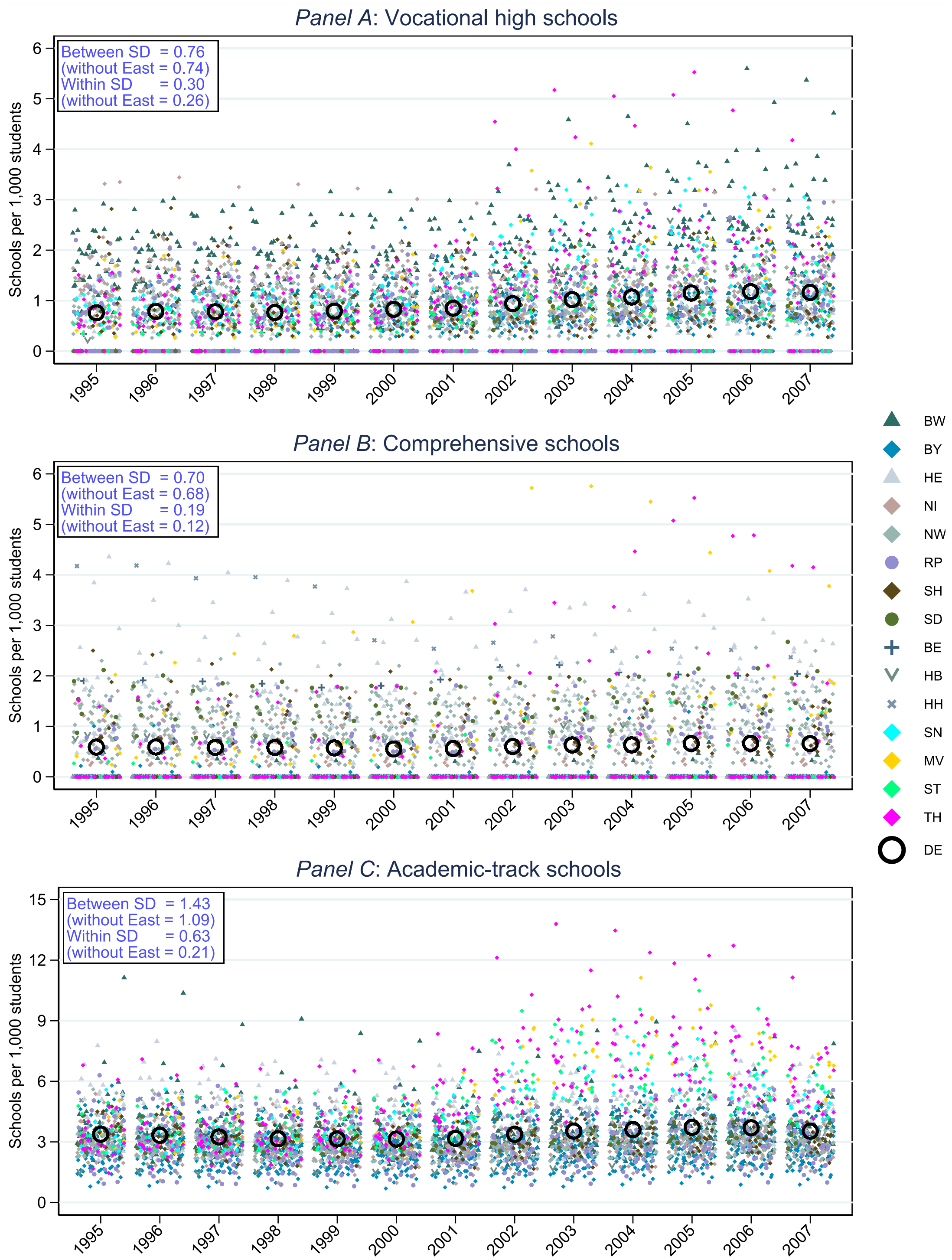

Fig. 2. School supplies by county and entry cohort. *Notes:* Each point identifies a county × cohort pair. Colors/symbols indicate the state: BW = Baden-Wurttemberg, BY = Bavaria, HE = Hesse, NI = Lower Saxony, NW = North Rhine Westphalia, RP = Rhineland Palatina, SH = Schleswig-Holstein, SD = Saarland, BE = Berlin, HB = Bremen, HH = Hamburg, SN = Saxony, MV = Mecklenburg-Vorpommern, ST = Saxony Anhalt, TH = Thuringia. Eastern German states are in bright ('neon') colors. Hollow circles indicate the national average. Between (within) SD indicates the school supply measure's standard deviation conditional on cohort (and county) fixed effects, with or without the Eastern German states. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

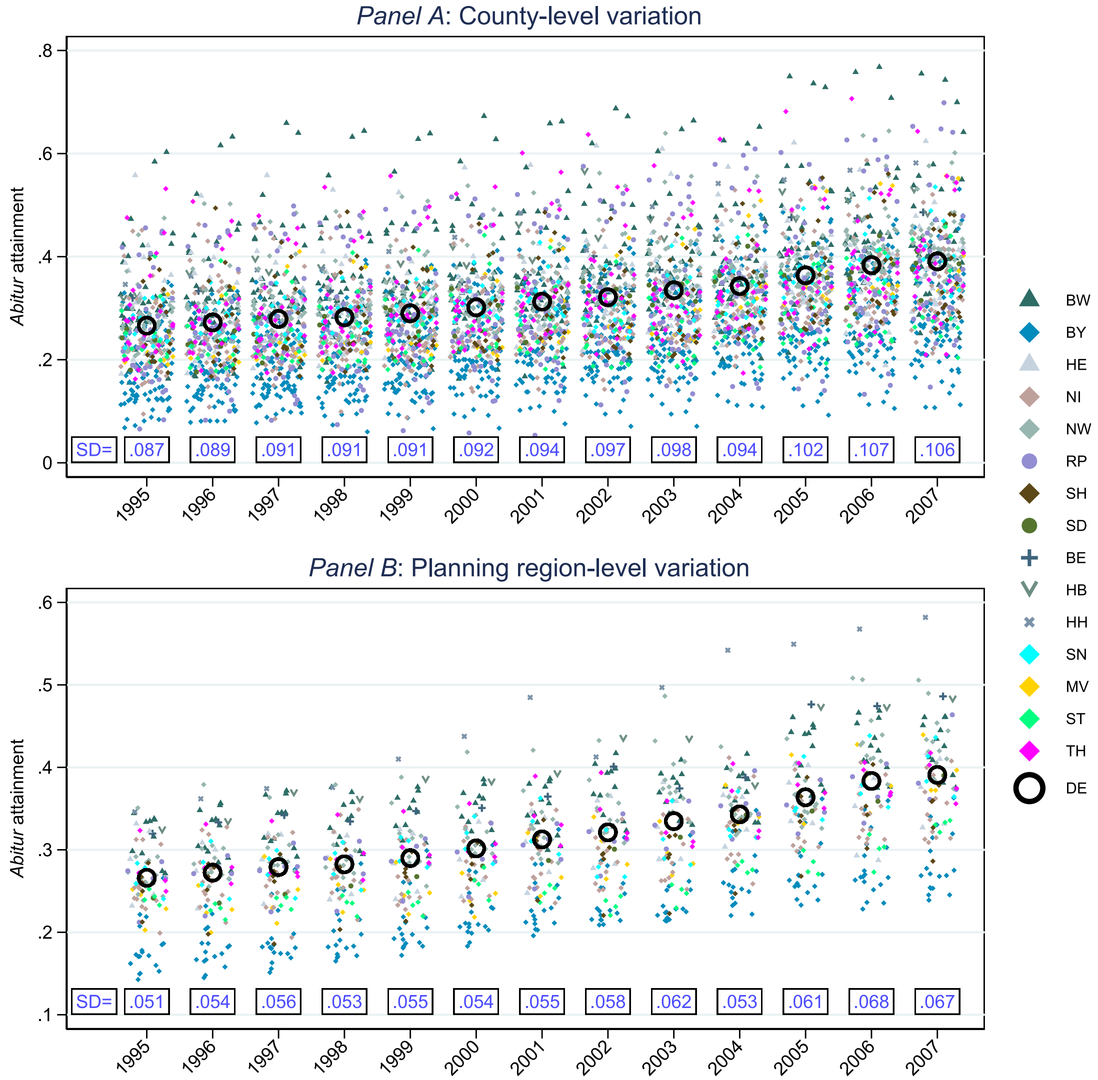

Fig. 3. Share of *Abitur* attainment by region and entry cohort. *Notes:* Each point identifies a region × cohort pair: panel A at the county, panel B at the planning region level. Colors/symbols identify states (see Fig. 3). Eastern German states are in bright ('neon') colors. Hollow circles identify the national average. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Fig. 3 presents a scatter plot of *Abitur* attainment at the county (panel A) and planning region (panel B) level across cohorts.[24] The national average of *Abitur* attainment (depicted by black hollow circles) monotonically increases from about 27% for the cohort that entered secondary school in 1995 to almost 40% for the 2007 entry cohort, showing overall educational expansion. More importantly, the figure reveals large regional heterogeneity in attainment both across and within states. In addition to well-known between-state differences (e.g., comparatively low *Abitur* attainment in Bavaria and high rates in the city states Berlin, Bremen, and Hamburg), the figure also shows that a sole focus on the state level (as is common in the German educational literature) misses a lot of variability at lower levels. In particular the differences between counties are very stark, with attainment rates ranging from only slightly above 10% to close to 80% in later cohorts. Due to the measurement problem described above, differences between counties might be slightly overstated, so that the most extreme values should be interpreted with some caution. However, large regional variation within states is apparent even at the level of planning regions, which are considerably larger than counties—in fact, clearly too large to depict regional inequality granularly—and thus do not suffer from these measurement issues. Importantly, both panels in Fig. 3 show that regional dispersion of attainment is increasing over time (see the reported standard deviations).

county but switch to, say, a vocational high school in the city for *upper*-secondary education. (Again, note that rural students who directly enroll in an urban secondary school after primary school—the much more common phenomenon—do not cause a measurement problem because they would count towards the city's cohort size.) Once we aggregate to the level of planning regions, which aggregate over large cities and their surrounding sub-urban/rural areas, this problem disappears. For the county-level analysis, in the case of three Bavarian rural–urban county pairs (*Bamberg* and *Bamberg, Stadt*; *Schweinfurt* and *Schweinfurt, Stadt*; *Würzburg* and *Würzburg, Stadt*) the problem was particularly severe as the three respective rural counties did not have a single upper secondary school in some of the (early) years. We aggregated each of these pairs into one 'county' (thus reducing the total number of counties by three). We do not extend this method of consolidation to other cases where supply levels in the rural county are low (but not zero), because it would involve arbitrary decisions about which counties to merge. Instead we present results at pre-defined higher levels of aggregation, which we deem a more transparent approach.

[24] Online Appendix Figure B2 visualizes the county-level variation by heatmaps for selected cohorts.

Our final analysis dataset covers the secondary school entry cohorts 1995 to 2007 for 379 counties and 91 planning regions, respectively.[25] The reduced number of regions arises because we are forced to exclude the state of Brandenburg due its incomparable statistical definition of comprehensive schools.[26] In addition to attainment rates and the three measures of school supply, our dataset contains a number of regional socio-demographic variables, used to proxy demand-side factors of educational expansion: unemployment rate, average household income, average population age, share of foreign students, share of college-educated workers, and urbanization level. We retrieve these variables from the INKAR data base (German Federal Institute for Research on Building, Urban Affairs and Spatial Development) at the county level and aggregate them up to the level of planning regions by constructing population-weighted averages over the counties that constitute each planning region. Online Appendix Table B2 provides summary statistics of all key variables for different samples.

4. Empirical strategy

The goal of this paper is to assess whether the availability of alternative pathways to *Abitur* affected attainment rates. We start by exploiting the large regional variation in the types of schools locally available to students by means of OLS regressions for the *Abitur* attainment rate, Y_{ic}, of entry cohort c from region i on our three measures of school supply, S_{ic}^j for $j \in \{V, C, A\}$:

$$Y_{ic} = \beta_C S_{ic}^C + \beta_V S_{ic}^V + \beta_A S_{ic}^A + \theta_c + \varepsilon_{ic}. \quad (1)$$

Due to cohort fixed-effects, θ_c, our coefficients of interest, β_C, β_V and β_A, are estimated only from contemporaneous *between-region* variation in the supplies of comprehensive, vocational, and academic-track schools, and not from secular trends in attainment and school supply. Here, and throughout the paper, we cluster standard errors at the level of regions.

Pending further investigation, the cross-sectional associations estimated in Eq. (1) hold merely descriptive value because all three school supply measures are potentially endogenous: local demand-side factors connected to educational aspirations, as well as other (state-level) educational policies, might affect both the local availability of different school types and attainment rates. To gauge the extent of confounding in the estimated cross-sectional associations, we probe their sensitivity to conditioning on (i) the extensive list of socio-demographic and structural variables described in the previous section and (ii) state fixed-effects so that our coefficients of interest are identified only from within-state variation in supply, holding state-level factors (e.g., educational policies) constant. Especially the *differential* sensitivity of the three school supply effects to this exercise can be informative of the relative levels of confounding concerning each coefficient. Still, it is clear that conditioning on these observables alone cannot provide convincing estimates of causal supply-side effects.

Consequently, we turn to two-way fixed-effects (TWFE) models, which add region-fixed-effects, δ_i, to Eq. (1):

$$Y_{ic} = \dot{\beta}_C S_{ic}^C + \dot{\beta}_V S_{ic}^V + \dot{\beta}_A S_{ic}^A + \dot{\delta}_i + \dot{\theta}_c + \dot{\varepsilon}_{ic}. \quad (2)$$

As fixed-effects absorb all permanent differences between regions and cohorts, in Eq. (2) the supply-side effects are identified only from *between-region cross-cohort* variation in school supply. The differential expansion (or contraction) of different school types between regions over time and differences in the size of adjacent cohorts offer much more plausibly exogenous variation in supply than the purely cross-sectional variation exploited above. To test if regions with expanding school supply had differential attainment growth already prior to the supply expansion, we can further add region-specific linear cohort trends in Eq. (2). Caveats of TWFE include that it uses much less treatment variation and that it requires relatively strong parametric assumptions, including treatment effect homogeneity, to estimate a well-defined causal parameter (e.g., Callaway et al., 2024).

Therefore, finally, we exploit the discrete nature of the introduction of new comprehensive and vocational high schools as 'natural experiments' in a difference-in-differences (DD) or event-study design. That is, we compare how *Abitur* attainment changes in regions that introduce their first comprehensive or vocational high school with the change in regions that continue to have no such alternative pathway to *Abitur*.[27] Under the assumption of parallel counterfactual attainment trends between those regions, DD identifies the effect of the *introduction* of these schools (i.e., the extensive margin effect of having at least one such school *vs.* none, ignoring the level of supply) on attainment for the counties that introduce such schools for the first time during our observation period (i.e., the average treatment effect on the treated; ATT).

While thus more limited in scope, DD is clearly the cleanest research design in our setting as it imposes no restrictions on treatment effect heterogeneity and only uses sharp—and well understood—jumps in school supply for identification. While local educational demands can be expected to influence the bureaucratic decision to introduce certain school types in the long run, from the perspective of families, the exact timing of when a new school starts operating may in fact be close to random, so that at the time-discontinuity of the school's creation, DD identifies a pure supply-side effect. Even though the identifying assumption of parallel trends is not directly testable, we can inspect 'pre-trends', i.e., if the attainment of 'treated' and 'control' regions develops in parallel prior to the introduction of the new school types. As for both new school types we have counties switching into treatment in almost every year throughout our observation period, it is hard to imagine how parallel trends could be violated while parallel pre-trends hold (and *vice-versa*).

Traditionally, DD would have been estimated by a TWFE regression, i.e., by replacing the continuous school supply measures in Eq. (2) with a binary treatment variable indicating the presence *vs.* absence of the school type in question. However, a recent literature has shown that, in settings with staggered treatment adoption like ours, this regression does not identify the desired ATT unless treatment effect are homogeneous, as it involves undesirable comparisons between early-treated and later-treated units (Goodman-Bacon, 2021). Therefore, we instead rely on the robust DD estimator by Callaway and Sant'Anna (2021), which avoids the problematic comparisons by estimating all admissible 2×2 DDs using only the never-treated units as controls.[28] The resulting group-time-specific ATT estimates can be aggregated to form different summary parameters of interest. We focus mainly on the event-study

[25] As expected graduation is (up to) nine years after secondary school entry, the 2007 entry cohort is the latest for which we still observe the relevant graduation numbers in our data which runs up to 2016. An advantage of stopping with the 2007 entry cohort is that this is the last cohort not affected by a wave of reforms in 2010 (in Berlin, Bremen, and Hamburg), which relabeled many schools as comprehensive with sometimes unclear changes at the school level.

[26] In 2005 Brandenburg adopted the standard definition of comprehensive schools. Accordingly, its data is incomparable to the rest of Germany in the years before 2005, but also internally incomparable over time.

[27] Note that the DD design only works for comprehensive schools and vocational high schools because academic-track schools are present in across all counties and periods.

[28] In particular, the ATT for period t (here measured in entry cohorts) for treatment cohort group g (all counties i where treatment turns on in cohort g) is identified by the 2×2 DD between that treatment cohort group ($G_i^g = 1$) and the never-treated control group ($C_i = 1$) between the treatment cohort group's pre-period (i.e., cohort $g - 1$, or cohort $g - 1 - \delta$ if there is anticipation of δ periods) and the post-period in question, t: $ATT(g, t; \delta) = E\left[Y_t - Y_{g-\delta-1} \mid G^g = 1\right] - E\left[Y_t - Y_{g-\delta-1} \mid C = 1\right]$. The Callaway and Sant'Anna (2021) estimator is simply the sample analogue of this expression.

Table 1
Cross-sectional OLS regressions for *Abitur* attainment rates at the county level.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Vocational high school	0.070***			0.055***	0.053***	0.043***	0.049***	0.051***
	(0.006)			(0.005)	(0.005)	(0.005)	(0.004)	(0.004)
Comprehensive school		0.037***		0.025***	0.034***	0.014**	0.006	0.008
		(0.007)		(0.006)	(0.005)	(0.007)	(0.006)	(0.005)
Academic-track school			0.033***	0.021***	0.026***	0.031***	0.013***	0.027***
			(0.003)	(0.003)	(0.003)	(0.003)	(0.002)	(0.004)
Weighted by cohort size					✓			
State fixed effects						✓		
Demand side controls							✓	✓
Excluding Eastern states								✓
Cohort fixed effects	✓	✓	✓	✓	✓	✓	✓	✓
Mean *Abitur* att. rate	0.30	0.30	0.30	0.30	0.32	0.30	0.30	0.30
R^2	0.402	0.195	0.342	0.519	0.560	0.606	0.700	0.774
N counties	379	379	379	379	379	379	379	322
N observations	4927	4927	4927	4927	4927	4927	4927	4186

Notes: This table presents results from county-level OLS regressions for *Abitur* attainment rates. Standard errors are clustered at the county level. The three school supply variables measure the number of schools per 1000 students. Demand side controls are: unemployment rate, average household income, average age, share of foreign students, college-educated share of workers and level of urbanization. The Eastern German states excluded in column 8 are: Mecklenburg-Vorpommern, Saxony, Saxony-Anhalt and Thuringia (Brandenburg is excluded throughout and Berlin is retained throughout). All regressions include dummies for the double graduation cohorts and the final pre-reform cohorts resulting from the G8 reform. Stars indicate significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

parameters, which describe the average effect of having introduced the school type in question on attainment e years after the treatment was adopted (where $e = 0$ refers to first treated cohort), across all units observed to have participated in the treatment for exactly e years, for different 'event-times' e.[29] The event-study allows us to inspect treatment effect dynamics and, most importantly, pre-trends, therefore immediately integrating a test for the design's validity.[30]

5. Results

5.1. Cross-sectional regressions

In Table 1 we present results for OLS regressions of Eq. (1) at the county level, which show that cross-sectionally all three upper-secondary school types correlate positively with attainment. Both the bivariate models in columns 1–3, as well as the joint one in column 4 suggest that the association between local school supply and attainment is strongest for vocational high schools, with a coefficient close to (more than) double the size of that for comprehensive schools (academic-track schools). This pattern is unchanged when we weight counties by their population size to obtain 'effect' estimates representative at the student level (column 5). It is hardly altered when restricting attention to within-state comparisons through the inclusion of state fixed-effects (column 6).

In column 7, we condition on the full set of socio-demographic controls as proxies for local demand-side factors driving *Abitur* attainment: unemployment rate, average household income, average population age, share of foreign students, share of college-educated workers, and urbanization level. The substantially increased R-squared indicates that these factors indeed explain a lot of between-county differences in attainment. Their inclusion substantially attenuates the coefficients for comprehensive and academic-track schools, suggesting that local supply of these schools reflects the social composition of resident families and local labor-market demands. Consequently, the cross-sectional supply-attainment correlations for these school types appear to be largely spurious. The coefficient for vocational high schools, in contrast, is left almost completely unchanged. This is strong initial evidence that the association between the local supply of vocational high schools and attainment reflects not just confounding but also causal supply-side effects.

As explained above, it is crucial to check whether these results are robust to two challenges in particular. First, it is unclear whether large increases in our measures of school supply in East Germany after 2000 reflect actual expansions in the number of available slots per student, because they are driven mainly by demographic decline instead of the introduction of new schools. Hence, in column 8 of Table 1 we exclude all East German states. This leaves the coefficients for comprehensive and vocational high schools unchanged but increases the one for academic-track schools, confirming that the demographically driven supply increases in East Germany correlate much less with attainment than the remaining variation. Still, the coefficient for academic-track schools remains only half the size of that for vocational high schools.

Second, students who attend upper-secondary school in another county than where they attended lower-secondary school might cause systematic measurement error that upward-biases our estimated school supply-attainment correlations. We test against these issues by repeating the analysis at the level of planning regions, where post-grade 7 student mobility should be largely absent. Online Appendix Table B3 repeats the complete analysis at the planning region level (excluding state fixed-effects, because most states comprise too few planning regions for this analysis to be meaningful). It confirms that all results carry over almost exactly to this substantially higher level of regional aggregation.

5.2. Two-way fixed-effects

Table 2 presents the regression results for the TWFE model of Eq. (2). The first four columns, where the estimated models are identical to those in Table 1 except for added county fixed-effects, show that

[29] In particular, the event-study coefficient for event-time e equals: $\theta(e) = \sum_{g\in\mathcal{G}}\sum_{t=1996}^{2007} w(g,t)\,ATT(g,t)$, where $w(g,t) = \mathbb{1}\{g+e \leq 2007\}\,\mathbb{1}\{t-g = e\}\,P(G^g = g \mid G + e \leq 2007)$ and $\mathcal{G}$ is the set of all treatment cohort groups.

[30] The undesirable comparisons of the 'static' TWFE DD would also be avoided by the fully saturated event-study TWFE regression: $Y_{ic} = \sum_{t=-12}^{11}\beta_j^t\,\mathbb{1}[I_{ic}^j = t] + \delta_i + \theta_c + \varepsilon_{ic}$, where I_{ic}^j indicates 'event-time' (measured in cohorts) with respect to the introduction of school type $j \in \{C, V\}$ in region i (i.e., $I_{ic}^j = 0$ indicates the cohort of introduction). However, this regression can suffer from a different form of contamination bias (Goldsmith-Pinkham et al., 2024; Sun & Abraham, 2021). Therefore, we focus on the Callaway and Sant'Anna (2021)-based event-study. However, in Online Appendix Figure B7 we show that results from the traditional fully-saturated TWFE event-study are virtually indistinguishable in our case.

Table 2
Two-way fixed-effects OLS regressions for *Abitur* attainment rates at the county level.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Vocational high school	0.013***			0.017***	0.012***	0.015***	0.017***	0.020***	0.020***
	(0.002)			(0.002)	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)
Comprehensive school		0.001		0.001	−0.006	−0.002	0.011	0.013**	0.005
		(0.009)		(0.008)	(0.016)	(0.005)	(0.008)	(0.005)	(0.010)
Academic-track school			−0.003*	−0.005***	−0.004***	−0.007***	0.005	0.010***	0.005
			(0.001)	(0.001)	(0.002)	(0.001)	(0.003)	(0.003)	(0.005)
Weighted by cohort size					✓				✓
County-specific linear trends						✓		✓	✓
Excluding Eastern states							✓	✓	✓
County fixed effects	✓	✓	✓	✓	✓	✓	✓	✓	✓
Cohort fixed effects	✓	✓	✓	✓	✓	✓	✓	✓	✓
Mean *Abitur* att. rate	0.30	0.30	0.30	0.30	0.32	0.30	0.30	0.30	0.32
R^2	0.950	0.949	0.949	0.951	0.950	0.970	0.957	0.973	0.972
N counties	379	379	379	379	379	379	322	322	322
N observations	4927	4927	4927	4927	4927	4927	4186	4186	4186

Notes: This table presents results from county-level OLS regressions for *Abitur* attainment rates. Standard errors are clustered at the county level. The school supply variables are measured as the number of schools per 1000 students. The Eastern German states excluded in column 8 are: Mecklenburg-Vorpommern, Saxony, Saxony-Anhalt and Thuringia (Brandenburg is excluded throughout and Berlin retained throughout). All regressions include dummies for the double graduation cohorts and the final pre-reform cohorts resulting from the G8 reform. Stars indicate significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

the coefficients for each school type are substantially reduced compared to the cross-sectional case. Nevertheless, the effect for vocational high schools remains positive and highly significant. The remaining columns show its robustness to weighting the sample by cohort size, including county-specific linear cohort trends, excluding the Eastern German states from the sample, and all combinations of these. This seems to confirm that the correlation between vocational high school supply and attainment is not purely spurious but reflects causal supply-side effects. The coefficients indicate that a supply increase of one school per 1000 students, which is slightly more than a one standard deviation increase in the cross-section (which equals 0.76, see Fig. 2) and corresponds to an increase of about one slot per 100 students (see Online Appendix Figure B1), increases the *Abitur* attainment rate on average by about 1.5 pp against a baseline of 30 percent.

The effect of comprehensive school supply is close to, and statistically indistinguishable from, zero across models when the Eastern states are included. When they are excluded, the coefficient turns positive but remains small and reaches statistical significance only in column 8. As anticipated, the estimated effect of academic-track school supply is most sensitive to the in- or exclusion of the Eastern states: with them, the estimated effected is consistently negative; without them, the coefficient turns positive but remains small and reaches statistical significant only in column 8, like for comprehensive schools. In line with the cross-sectional results from above, these results suggest that even if there are supply-side effects for comprehensive and academic-track schools, they are only half as large as those for vocational high schools.

In Online Appendix Table B4 we repeat all regressions at the level of planning regions. The effect estimates for vocational high schools closely reproduce those at the county level (with only marginally smaller effect sizes), whereas those for comprehensive and academic-track schools become even less suggestive of positive effects. Altogether, the TWFE estimates therefore suggest that supply increases of vocational high schools increase *Abitur* attainment rates, whereas for comprehensive and academic-track schools we cannot reject the null hypothesis of no supply-side effects.

5.3. Event-study

In the final step of our analyses we exploit the sharp nature of the introduction of new schools as ‘natural experiments’ in an event-study design. This allows us estimate the extensive margin effects of the local availability of the two new school types.[31]

For the event-study for vocational high schools, we exclude 232 ‘always-treated’ counties where these schools are present throughout our observation period.[32] 50 ‘never-treated’ counties have no such school throughout and serve as the control group. In 90 ‘treated’ counties a vocational high school is introduced for the first time during our observation period.

We remind the reader that everywhere but in Bavaria, these events refer to the opening of a new vocational high school. This means that students who were finishing lower-secondary school, i.e., transitioning from grade 10 to grade 11, at the time of opening (i.e., the county’s first treated cohort according to our coding) are the first who can make use of the new pathway towards *Abitur*. In Bavaria, in contrast, these events refer to the addition of a thirteenth school year to an *already existing* FOS school. Hence, not only students who were transitioning from grade 10 to grade 11 at the time of the event, but also those who were already enrolled in the FOS in grades 11 or 12 (i.e., the county’s two pre-treatment cohorts according to our coding) can make use of the new pathway simply by completing the newly added grade 13 on their FOS. This suggests that in Bavaria the treatment also partially affects students in the two pre-treatment cohorts.[33] Therefore, whenever the sample includes Bavaria, we allow for two periods of treatment anticipation, i.e., we only assume parallel trends up until three cohorts prior to treatment, and define $e = -3$ instead of $e = -1$ as the base period (where e refers to event-time) (Callaway & Sant’Anna, 2021).[34]

[31] Note that the event-study analysis is not possible for academic-track schools, which are available in all counties at all times. Neither is it feasible at the planning region level due to an insufficient number of observations.

[32] We also exclude 7 counties that switched from treated to untreated.

[33] In earlier-treated Bavarian counties, where the grade-13 FOS was tested as a pilot (see Online Appendix A), it is unlikely that students knew at the time of enrolling that grade 13 would be added to their FOS. In later-treated counties, it is likely that at least some students knew and thus purposefully chose to enroll in FOS as an alternative pathway towards *Abitur*.

[34] Note that this means that in the estimations including Bavaria, counties treated before 1998 are dropped, as they are not observed in $e = -3$. This is the case for 16 Bavarian counties and 4 counties outside of Bavaria. Accordingly, the event-study for the whole of Germany comprises only 70 (instead of 90) treated counties. The event-study for only Bavaria comprises 52 treated (and 23 never-treated) counties. For the event-study excluding Bavaria, where the

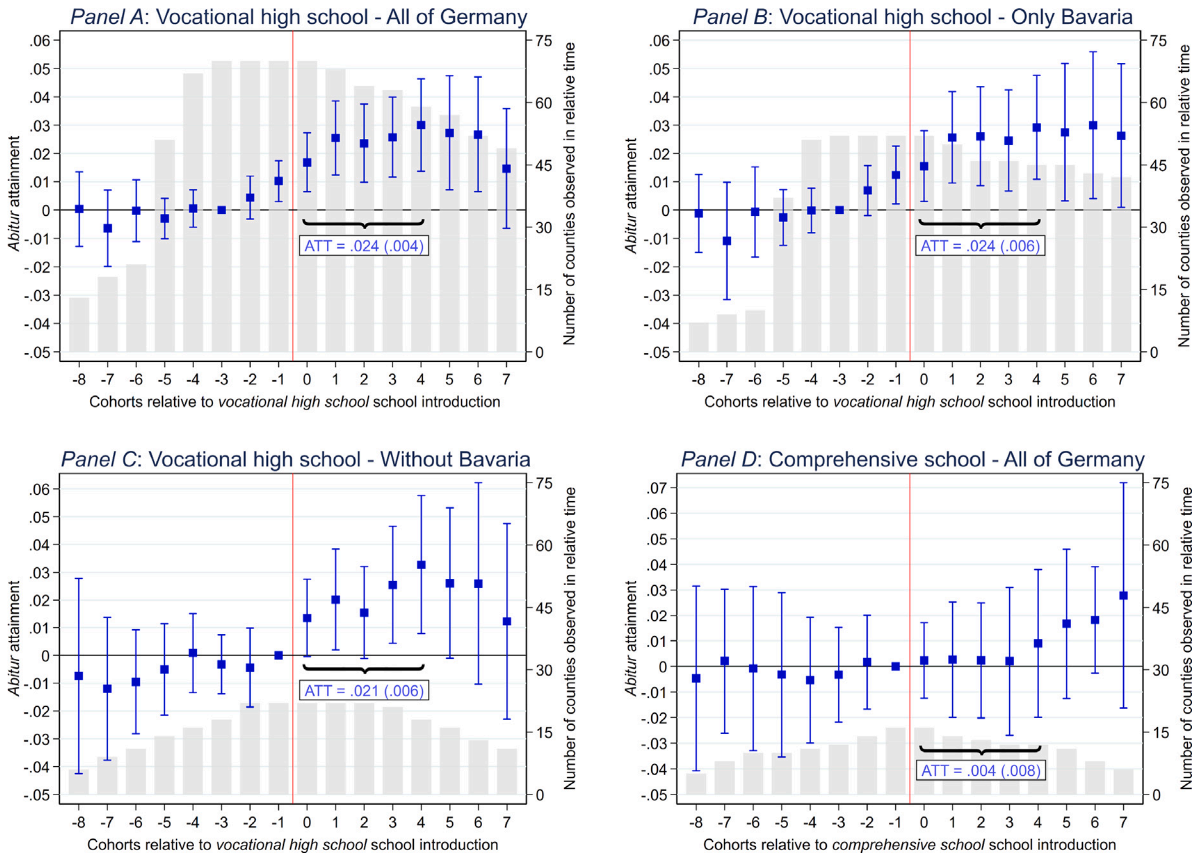

Fig. 4. Event-studies for introduction of vocational high schools and comprehensive schools at the county level. *Notes:* The figure plots the event-study coefficients including 95%-confidence intervals (from a bootstrap clustered at the county level, and adjusted for multiple hypothesis testing) for the introduction of vocational high schools/comprehensive schools, estimated by the Callaway and Sant'Anna (2021) DD estimator (Online Appendix Figure B7 shows the analogous event-studies estimated by TWFE regressions). Coefficients represents the 'long-difference' to the baseline period, where treatment-control differences are normalized to zero. In panels A and B the baseline period is −3, in panels C and D it is −1. Sample sizes for each panel are mentioned in the text. Additionally, we display the aggregated ATT estimate over the first five treated cohorts.

For the event-study analysis of comprehensive schools, we exclude 133 'always-treated' counties where these schools are present throughout our observation period.[35] 226 'never-treated' counties have no such school throughout and serve as the control group. Only in 16 'treated' counties a comprehensive school is introduced for the first time during our observation period, so that the estimates are potentially more specific to the treated counties at hand and statistical power is lower than for vocational high schools. They refer to the opening of a new comprehensive school everywhere, so there is no reason to allow for anticipation.

Fig. 4 presents the event-study estimates. Note that, as treatments are staggered across (almost) every entry cohort between 1996 and 2007, our panel, which is balanced in cohorts, is extremely unbalanced in event-time.[36] Accordingly, the sample of treated counties used to estimate the treatment leads and lags changes substantially across different event-times. In particular, the most extreme leads and lags are estimated from only a handful (in some cases a single) units. As these compositional changes complicate the interpretation of the event study, in Fig. 4 we restrict attention to eight treatment leads and lags, where the sample is more (though still far from fully) balanced, and indicate the number of treated counties observed at each event-time by gray bars. By the same token, we report the aggregated ATT over the first five cohorts after the respective new school's introduction as our preferred summary parameter.[37]

Panel A of Fig. 4 shows the event-study for vocational high school introduction for the entire sample, including Bavaria. As discussed above, we allow for two cohorts of anticipation, which implies that the difference in *Abitur* attainment between treated and control counties is normalized to zero in event-time $e = -3$. Prior to that, there is no evidence of differential attainment trends between counties that go on to introduce a vocational high school and those that do not. However, two cohorts prior to the introduction trends start to diverge, as attainment in treated counties increases relative to the controls. This might be due to genuine violations of the parallel trends assumption or simply due to the fact that in Bavaria the two pre-treatment cohorts are partially treated. Accordingly, in Panels B and C we perform the event-study separately for Bavaria and the rest of Germany. This reveals that the two divergent treatment leads are indeed a phenomenon pertaining to Bavaria, whereas elsewhere pre-trends are parallel until right before treatment. This suggests that the timing of vocational high school openings is indeed quasi-random, so that the estimates can be interpreted causally.

problem is absent, we use $e = -1$ as the base period to retain those 4 counties, resulting in 22 treated and 27 never-treated counties.

35 We also exclude 4 counties that switched from treated to untreated.

36 The treatment events are depicted in Online Appendix Figures B4 (for vocational high schools in Bavaria), B5 (vocational high schools in the rest of Germany), and B6 (for comprehensive schools).

37 Alternative aggregations proposed by Callaway and Sant'Anna (2021), like the simple average of all group-time-specific ATT's or the average over treatment cohort-specific ATT's, both of which place more weight on distant event-times for which samples are more selected and the parallel trends assumption might be less plausible, deliver almost identical results.

The estimated aggregate ATTs equal about 2.4 pp in all three samples. In terms of treatment effect dynamics, in non-Bavarian counties the opening of a vocational high school induces a sudden jump in *Abitur* attainment rates of about 1.5 pp, after which the effect grows to about 2.5 pp. As the treated sample becomes very small after event-times larger than five, the small and insignificant decreases thereafter should not be overinterpreted. In Bavaria, the effect starts to increase in $e = -2$ until it also stabilizes at about 2.5 pp around $e = 1$. This pattern corresponds to expectations: most students in the $e = -2$ cohorts, especially those in the early adopting Bavarian counties, were probably unaware of the fact that a thirteenth grade would be added to their FOS school at the time of enrolling, so that only those who enrolled for other reasons than to obtain the *Abitur* were treated. With increasing event-time (and calendar time), the possibility to attain the *Abitur* on an FOS will have been more widely known at the time of enrollment, so that more students are affected. The general finding of increasing treatment effects after $e = 0$ can be explained by the facts that (i) newly opened schools might gradually expand their capacity, (ii) treatment only indicates the first vocational high school but more might be opened in the county in the following years, and (iii) knowledge of the new pathway to the *Abitur* might only gradually snowball across student cohorts.

Altogether, the event-study estimates provide strong evidence for a causal extensive margin effect of vocational high school introductions on *Abitur* attainment rates of about 2.4 pp against a baseline of 25 percent (the mean for treated and never-treated counties). This corroborates the findings from our above analyses using continuous school supply measures and thus lends credence to their causal interpretation. Likewise, the event-study for comprehensive school introductions in Panel D of Fig. 4 also confirms our previous finding of no effect. Slightly increasing point estimates at larger event-times are likely due to the increasingly specific sample.

6. Conclusions

This paper investigated the gradually increasing flexibility of Germany's tracked school system. The university-entrance certificate (*Abitur*) was traditionally only awarded by academic-track schools until the introduction of vocational high schools and comprehensive schools opened up new pathways towards the certificate. Accordingly, upper-secondary schooling has been partially de-tracked wherever these schools became locally available. To shed light on the effects of this decentralized and incremental 'de-tracking at the margin' we estimate how the local supplies of academic-track schools, comprehensive schools and vocational high schools affect local *Abitur* attainment rates.

We use administrative data that covers the universe of German students, schools, and graduates to construct a county-level panel of local school supply and upper-secondary attainment for 13 cohorts between 1995 and 2007. This novel data set reveals that the expansion of secondary credentials on net masks important geographical heterogeneity: *Abitur* attainment varies strongly between counties and these differences are increasing over time. Also, the number and types of schools locally available to students differs markedly between regions (and less over time).

We find a strong cross-sectional associations between the supply levels of all three school types that award the *Abitur* and its attainment. However, for academic-track and comprehensive schools, these correlations can largely be accounted for by regional differences in educational demand, as proxied by the degree of urbanization and the social composition of resident families. Consistent with the absence of substantial supply-side effects, for these school types we fail to find significant coefficients in two-way fixed-effects (TWFE) and, for comprehensive schools, event-study models that only use between-region cross-cohort variation in school supplies.

Accordingly, their local availability seems to have mainly facilitated already ongoing processes of educational expansion, but had these schools not been locally available, most of its current graduates would have found other ways to attain the *Abitur* (e.g., through upgrading to an academic-track or vocational high school after completing the lower-secondary grades at an intermediate-track school).[38] This might be less surprising for the traditional academic-track schools, which expand their slots only slowly in response to persistent demand-side pressures by parents (Helbig & Sendzik, 2022). For comprehensive schools, however, this result stands in contrast to the weight these schools have received in the public debate. The reason for their limited effectiveness in raising *Abitur* attainment might be a mismatch between their original ambition to move the system towards comprehensive schooling and their actual implementation, which meant that they coexist with traditional track-specific schools, in particular academic-track schools. Clearly, the latter are more attractive for students with university aspirations. As a consequence, in many places, comprehensive schools effectively function as substitutes for intermediate- and low-track schools (Puhani & Weber, 2007).

For vocational high schools, in contrast, we find clear evidence of a positive supply-side effect on attainment. Already the cross-sectional supply-attainment association is remarkably robust to controlling for various socio-demographic controls and state fixed-effects. The positive effect is confirmed in more plausibly causal TWFE regressions, across various model specifications and sample permutations. Finally, also our most credible research design, the event-study, confirms that the opening of a new vocational high school boosts *Abitur* attainment. Our estimates suggest that, at the extensive margin, the introduction of a single vocational high school, when it was not previously available in a county, increases attainment rates by about 2.4 pp. Across extensive and intensive margins, a supply increase of one school per 1000 students (corresponding roughly to a one SD supply increase in the cross-section) increases attainment rates by roughly 1.5 pp against a baseline of 30 percent.

This implies that, in contrast to academic-track schools and comprehensive schools, vocational high schools induce a group of students to take up (and complete) academic upper-secondary education that otherwise would not have done so. This result is especially noteworthy as, unlike previous research (e.g., Schindler, 2017), we adopt a restrictive definition of upper-secondary attainment that focuses only on university eligibility (excluding certificates that merely grant access to the vocational sector of higher education). Despite having received relatively little attention in the public (and academic) debate, vocational high schools have thus contributed to educational expansion through a process of 'inclusion' (Arum et al., 2007). Our results confirm the importance of second-chance pathways for mitigating the risk of misallocation in tracked school systems (of high-ability students to low tracks) found in previous research (Dustmann et al., 2017; Mühlenweg & Puhani, 2010).

While a central reason for the success of vocational high schools is likely a reduction of students' (perceived) costs of upgrading, we suggest that another crucial factor resides in their hybrid nature: because they combine academic and vocational curricula, they might be especially attractive to more risk-averse low-SES students who, in the traditional system, would have been diverted towards VET given that its yields more direct labor market returns (Shavit & Müller, 2000). For these students, vocational high schools might partly solve the trade-off between short-term employability and long-term human capital investments. Whether increased university eligibility translates into increased university enrollment and/or better labor market outcomes, and in how far vocational high schools really contribute to reducing social inequality, are questions that need to be addressed by future

[38] This is consistent with Helbig and Sendzik (2022), who find that a summary measure of school structural modernization, which includes the supplies of academic-track and comprehensive schools, has no effect on Abitur attainment rates.

research based on individual-level data, given that answers to these questions determine if this is an attractive model to adopt also for other countries.

CRediT authorship contribution statement

Sönke Hendrik Matthewes: Conceptualization, Methodology, Software, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization, Funding acquisition. **Camilla Borgna:** Conceptualization, Writing – original draft, Writing – review & editing, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.econedurev.2024.102608.

Data availability

Data will be made available on request.

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