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Supply Shocks in the Market for Apprenticeship Training

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1. Introduction

In times of economic crisis and increasing costs of obtaining academic qualifications, a dual vocational system that combines firm-level training with vocational schooling is gaining popularity in many countries. For example, the United Kingdom and the United States recently launched programs to foster dual apprenticeship training tracks for young school leavers.[1] In addition, owing to the economic downturn following the COVID-19 pandemic, increasing youth unemployment rates are likely to raise policymaker interest in apprenticeship programs that smooth the transition from education to the labor market. Governments expect substantial returns with such investments, most importantly through improving young job seekers' employability, skills, and future careers.[2]

Along with the increasing policy interest in training young people, labor economists are paying more attention to the functioning of the market for apprenticeship training (e.g., Acemoglu and Pischke 1999; Stevens 1999; Blatter et al. 2016; Dustmann and Schönberg 2009; Cavaglia et al. 2020). Despite widespread research on apprenticeship markets, little is known about the effects of supply shocks. However, the supply of apprentices fluctuates frequently because of demographic changes and increasing academization, or depending on migration flows.

Our study aims to shed light on the effect of a positive supply shock on the equilibrium price and quantity in the market for apprenticeship training. To predict the possible outcomes, we first present a simple theoretical model of the market for two types of school graduates (lower secondary school and high school graduates). In competitive training markets and under the assumption that apprentices with different levels of education are substitutes, we expect that a one-time supply shock of high school graduates leads to an increase (decrease) in the number of apprenticeship contracts among apprentices with a high school (lower secondary school) degree and a decrease (increase) in the wage for high school (lower secondary school) graduates. However, the assumption of competitive markets may be particularly strong in the context of the German apprenticeship market, as apprentice wages are subject to collective bargaining agreements across a wide range of training occupations, and employer associations and unions are involved in many aspects of apprenticeship training, both formally and informally (Dustmann and Schönberg 2009, Ryan et al. 2013). To the extent that institutions in Germany lead to frictions in the apprenticeship market, theory predicts that a supply shock of highly educated apprentices

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[1] See https://www.dol.gov/newsroom/releases/eta/eta20200218 and http://researchbriefings.files.parliament.uk/documents/SN03052/SN03052.pdf.
[2] See Ryan (2001), and Wolter and Ryan (2011).

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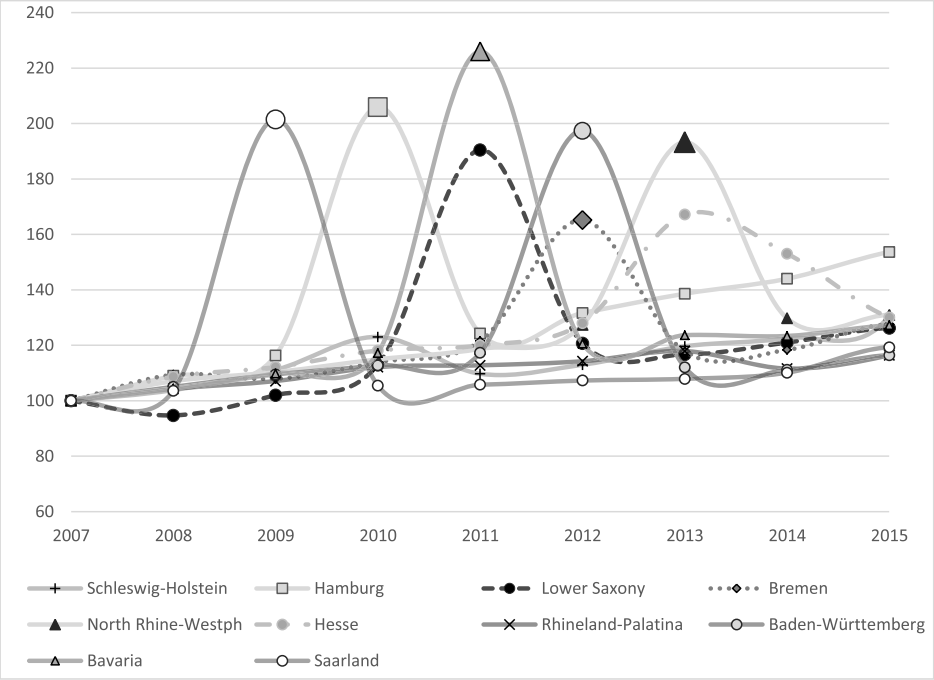

Figure 1. Number of high school graduates 2007–2015, West Germany
Source: Destatis (2016, 2019). Large symbols are years of double cohort. Cohort size is normalized to 100 in 2007.

would be absorbed by training firms if wages were below the competitive level prior to the supply shock. As a result, a positive supply shock would lead to more apprenticeship contracts without negatively affecting wages.

Our empirical identification strategy exploits the effects of a high school reform in Germany that reduced the duration of high school by one year, which resulted in two cohorts graduating in the same year in a particular state. We exploit regional variation regarding the timing of implementation (see Figure A1) to identify supply shock effects on the apprenticeship market. In Germany, the supply of apprentices with a high school degree is quantitatively important, as such applicants constitute a large and increasing minority of all apprentices. We apply difference-in-differences estimation techniques to empirically identify the effects of the school reform on the number of apprenticeship contracts and apprentice wages, and we also employ fixed-effects and an instrumental variables panel regression to identify the association between supply and apprenticeship contracts and wages.[3]

Our results suggest that the one-time supply shock due to the school reform led to a 7% increase in apprenticeship contracts, but we find no significant effects on wages. The effects are robust across different subsamples and identification strategies using both aggregate and firm-level data. However, we find that the high school reform most strongly affected occupations with a relatively low share of apprentices with a high school qualification prior to the reform. In sum, we provide strong empirical evidence for wage rigidity in the market for high school apprentices.

Our results have important implications. As firms cannot adjust wages downwards in the short run, supply shocks will only be absorbed by training firms if wages for apprentices with a particular educational qualification are below the competitive level. While the high school reform led to an increase in the supply of highly educated apprentices, other types of supply shocks (e.g., due to migration) may lead to an increase in the supply of apprentices with a lower education level. In such a case, the inability of firms to adjust wages would lead to a scenario of excess supply in the apprenticeship market, at least to the extent that firms expect a positive association between productivity and an apprentice's education level.

The remainder of the paper is organized as follows. Section 2 explains the German school and apprenticeship training system and the implementation of the high school reform. Section 3 presents the theoretical model of the market for apprentices, allowing for heterogeneity in apprentices' initial education levels. Section 4 describes the data, while Section 5 elaborates on our identification strategy. Section 6 presents the empirical results and examines the changes in the key indicators that have occurred since the implementation of the policy and the extent to which these changes can be attributed to the policy. Section 7 includes a discussion of our results. Section 8 concludes.

2. Secondary schooling and the apprenticeship system in Germany

In the German apprenticeship market, firms decide whether they want to post any vacancies for apprenticeship training, and individuals can in turn apply for advertised training positions. As shown in Figure A3, a large majority of graduates from lower-secondary school tracks enters an apprenticeship program. Conversely, the majority of high school graduates enroll in a university or university of applied science, although a large minority of 34% of high-school graduates embark on vocational training. Following a screening and selection process, the firm and apprentice then sign a training contract that specifies the wage, training and working conditions for the entire duration of the apprenticeship program. In principle, wage levels are determined by collective agreements between employers' associations and unions. These collectively bargained agreements usually refer to sectors and regions rather than occupations or specific groups of apprentices. For example, apprentice wages in collective agreements rarely differentiate between more experienced apprentices and those with different schooling backgrounds. This means that firms often pay one

[3] Previous studies have analyzed the relationship between school graduates and apprenticeship contracts (e.g., Baldi et al. 2014; Maier and Walden 2014 for Germany; Muehlemann et al. 2009 for Switzerland). However, demographic changes in the number of school graduates are typically small and the number of training contracts adjusts smoothly over time.

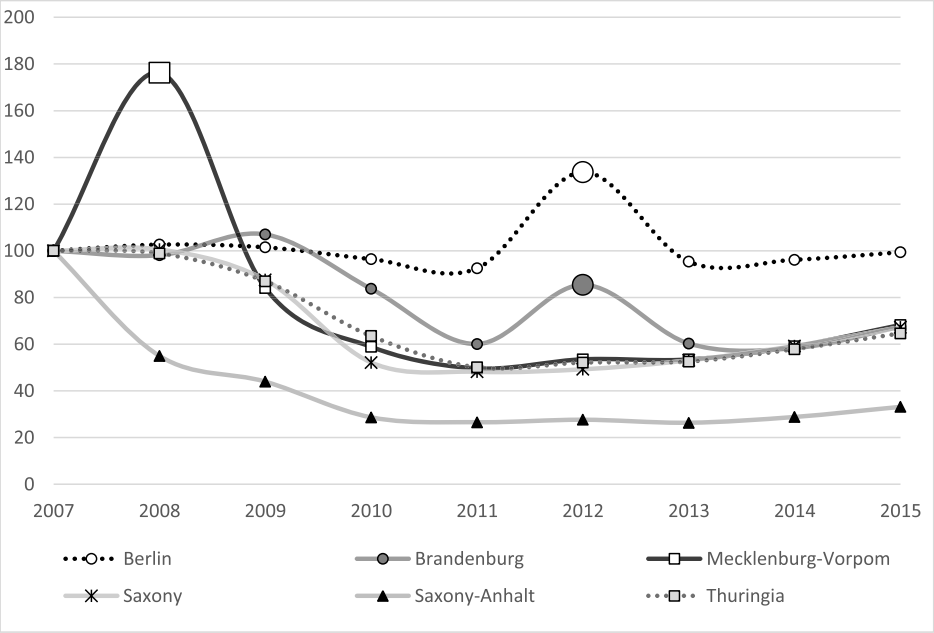

Figure 2. Number of high school graduates 2007–2015, East Germany
Source: Destatis (2016, 2019). Large symbols are years of double cohort. Cohort size is normalized to 100 in 2007.

fixed wage that does not vary at the firm level despite differences in apprentices such as age, education, or training occupation. Firms for which the collective agreements are not legally binding may deviate from their wage-setting rules by offering apprentice wages of no less than 20% below the minimum wage. Thus, such firms can, in principle, adjust wages in response to supply or demand shocks when hiring new apprentices. Signing a contract implies that the firm commits to the provision of training according to occupation-specific and nationally binding training curricula. At the end of the training period, apprentices take a standardized external exam to obtain their skilled worker qualification (*Facharbeiter*). The system is characterized by a broad coverage of occupations across all industries. Clerical occupations, technical and metal producing occupations, and traditional craft occupations are among the most popular apprenticeships. The median duration of an apprenticeship is three years. The 20 most popular training occupations account for approximately half of the 500,000 new apprenticeship contracts in Germany (BIBB, 2017b).

2.1. The high school reform

The high school reform resulted from Germany's commitment to the Bologna Process that aims to ensure the comparability of higher education qualifications across European countries. From 2001, most federal states (*Länder*) started timplementing the school reform by reducing the minimum duration of a high school degree (*Abitur*) by one year while keeping the curriculum content unaltered. The timing of the reform implementation was decided by each state individually (Figure A1). Consequently, the implementation took place in different years. Figures 1 and 2 show the increase in high school graduates in West Germany and East Germany, respectively. The increasing number of high school graduates is clearly visible in many states despite the overall number of graduates decreasing substantially in this period due to demographic change. In addition, the school reform caused the number of graduates to increase sharply at the time when the double cohort graduated in a particular state. In East German states, the number of school graduates dropped significantly in the period from 2007 to 2011. The main reason was the decline of the birth rate in East Germany after the reunification. Moreover, many people migrated to West Germany, but that trend slowed down considerably in recent years.

Due to the compressed high school curriculum, high school graduates with a shortened schooling duration could have different characteristics compared to those graduates from prior years. However, studies examining competency outcomes (Dahmann 2017) as well as dropout, performance, and motivation (Meyer and Thomsen 2017) find no effects, while other studies find moderate effects for school grades, the probability of grade repetition, and for personality traits such as neuroticism and emotional stability, although not for the level of conscientiousness (Büttner and Thomsen 2015; Dahmann and Anger 2014). Thus, we cannot rule out that the high school reform had some (adverse) effects on the skills development of the high school graduates, and this would potentially affect the transition rates into vocational training. Moreover, there may be uncertainty among training firms regarding the expected level of cognitive and non-cognitive skills of graduates who were affected by the high school reform. Thus, wages of apprentices with a high school degree who were affected by the reform would if anything, likely be lower compared to other cohorts. As high school graduates are younger on average at the time of graduation, this may also affect their probability to obtain an apprenticeship position. Finally, it is also possible that the high school reform affected the occupational choice of school graduates.[4]

In summary, the empirical findings suggest that—if any—the German high school reform had only small effects on the cognitive and noncognitive skills of high school graduates. From a firm's perspective,

[4] In general, the occupational choice in Germany is affected by different factors, including information campaigns in public schools, programs of the Federal Employment Agency, expected wages and career prospects or the expected work-life balance (Schnitzler 2019, Granato and Ulrich 2018). To test whether applicants affected by the high school reform made different occupational choices than in other years, we compare choices of applicants before and after the high school reform at the 1-digit occupation level. Based on aggregate applicant data from the Federal Employment Agency, we find that the shares of individuals applying for occupational groups differ only marginally in the year of the double cohort. Moreover, we do not find large shifts in the share of applicants according to age, gender, nationality, and migration background, neither in comparison to the year before, nor to the year following the high school reform. Thus, these statistics suggest that the occupational choice was not strongly affected by the high school reform.

this implies that the characteristics of potential applicants for apprenticeship positions with a high school degree are largely comparable before and after the high school reform.

3. Supply shocks in the German apprenticeship market

Supply shocks in the labor market are usually studied in the literature on immigration. Theoretical models often assume competition, production functions that allow for substitutability between workers, and wages that are fixed in the short run but flexible in the long run.[5] To develop a hypothesis on the possible effects of a one-time supply shock of high school graduates in the apprenticeship market, this section uses a simple static supply and demand framework.[6] In this model, two types of apprentices compete in the apprenticeship market.[7] High school apprentices x_A require a minimum of 12 to 13 years of education (A = *Abitur = high school/gymnasium graduates*), whereas apprentices from lower schools x_{NA} require 9 to 10 years of education (NA = *No Abitur = lower secondary school graduates*). Apprenticeship output y is produced according to a constant elasticity of substitution (CES) technology:

$$y = \left(\alpha x_A^{\rho} + (1-\alpha)x_{NA}^{\rho}\right)^{\frac{1}{\rho}}$$

where $0 < \alpha < 1$ is the constant share parameter and $-\infty < \rho \leq 1$ determines the degree of substitutability between x_A and x_{NA}.

The CES model with heterogeneous inputs of apprenticeship training and production, x_A and x_{NA} includes the possibility of unit elasticity of substitution ($\rho = 0$). It includes the possibility that productive occupational inputs of high and low educated apprentices – particularly in larger firms – are at least in part complementary ($\rho < 0$). Also it includes the possibility of substitution ($\rho > 0$), when training is for one occupation only.

In the market for heterogeneous apprenticeships, training firms are price takers. The marginal costs of apprenticeship contracting are fixed and differ between the two types, with $w_A \geq w_{NA} > 0$. Firms minimize their expected training costs subject to y:

$$minimize\ w_A x_A + w_{NA} x_{NA}$$

When short-run output $\bar{y}$ is constant, the respective input demand functions are[8]

$$x_A^*(w_A, w_{NA}, y) = \gamma \bar{y}\left(\frac{w_A}{\alpha}\right)^{\frac{1}{\rho-1}} \text{ and } x_{NA}^*(w_A, w_{NA}, y) = \gamma \bar{y}\left(\frac{w_{NA}}{1-\alpha}\right)^{\frac{1}{\rho-1}}$$

$$\text{with } \gamma = \left(\alpha\left(\frac{w_A}{\alpha}\right)^{\frac{\rho}{\rho-1}} + (1-\alpha)\left(\frac{w_{NA}}{1-\alpha}\right)^{\frac{\rho}{\rho-1}}\right)^{-\frac{1}{\rho}}.$$

The firm's cost function is

$$c(w_A, w_{NA}, y) = w_A x_A^*(w_A, w_{NA}, y) + w_{NA} x_{NA}^*(w_A, w_{NA}, y).$$

The marginal and average costs are the same and do not depend on the level of output:

$$\frac{c(w_A, w_{NA}, y)}{y} = \frac{\partial c(w_A, w_{NA}, y)}{\partial y} = \gamma\left(w_A\left(\frac{w_A}{\alpha}\right)^{\frac{1}{\rho-1}} + w_{NA}\left(\frac{w_{NA}}{1-\alpha}\right)^{\frac{1}{\rho-1}}\right).$$

3.1. An upward shock in the supply of x_A when the two inputs have unit elasticity of substitution

We first consider the case most commonly used in (immigration) studies of supply shocks in the labor market. This occurs when factor inputs x_A and x_{NA} have a unit elasticity of substitution ($\rho = 0$) and training output can be written as resulting from Cobb–Douglas technology as follows:

$$y = x_A^{\alpha} x_{NA}^{(1-\alpha)}.$$

Under competition, the input shares are independent of the relative costs w_A/w_{NA}. The marginal productivities for x_A and x_{NA} that result from the competitive equilibrium inputs before the introduction of the high school reform can be expressed, respectively, as

$$w_A = \alpha\left(\frac{x_A}{x_{NA}}\right)^{\alpha-1} \text{ and } w_{NA} = (1-\alpha)\left(\frac{x_A}{x_{NA}}\right)^{\alpha}.$$

The implications of a positive supply shock in x_A on the labor market conditions in the short run are set by the laws of supply and demand. When the supply curve for x_{NA} is upward-sloping and the demand curve is downward-sloping, a positive shock in the supply of x_A reduces the equilibrium input of x_{NA} (Borjas 2003). The shift in the supply of higher educated apprentices x_A lowers their productivity $\left(\frac{\partial w_A}{\partial x_A} < 0\right)$ and increases that of $x_{NA}\left(\frac{\partial w_{NA}}{\partial x_A} > 0\right)$.

Let x_i^t be the total number of apprenticeships, with $t \in \{0; 1\}$; $t = 0$ marks the point in time before the high school reform and $t = 1$ marks the point in time after the high school reform; $i \in \{A; NA\}$. The short-run outcomes are summarized as follows:

$$x_{NA}^1 < x_{NA}^0 \text{ and } x_A^1 > x_A^0$$

$$w_{NA}^1 > w_{NA}^0 \text{ and } w_A^1 < w_A^0.$$

The share of high school apprentices $x_A/(x_A + x_{NA})$ increases because short-run demand increases for x_A and decreases for x_{NA}.

3.2. An upward shock in the supply of x_A when the elasticity of substitution is less than unity

Next, even though this is an unlikely scenario for the heterogeneous apprenticeship market, we consider the case in which x_A and x_{NA} are complementary inputs producing y in fixed proportions. The short-run effect of a positive supply shock in x_A with x_{NA} remaining constant is comparable to the case of inelastic demand for x_A. In this case, the short-run effects in the apprenticeship market can be summarized as

$$x_{NA}^1 = x_{NA}^0 \text{ and } x_A^1 = x_A^0,$$

$$w_{NA}^1 = w_{NA}^0 \text{ and } w_A^1 < w_A^0.$$

The share of high school apprentices $x_A/(x_A + x_{NA})$ thus remains unchanged. In the short run, the productivity of lower school apprentices w_{NA} is constant, while w_A decreases.

3.3. What if wages are sticky?

Apart from implicit contracts and efficiency wages, several factors

[5] Pischke and Velling (1997) provide an empirical study of supply shocks in the German labor market. They find little to no evidence of substitution effects due to immigration. The more recent study by Dustmann et al. (2017) considers the heterogeneity between skilled and unskilled workers and finds a small decline in local wages and a substantial effect on unemployment due to immigration. This effect, however, is primarily due to firms reducing their input of new labor (diminishing their hiring rate). The authors find no evidence that firms increase their firing rate to make space for new workers. Thus, incumbent workers tend to be shielded from the supply shocks of foreign workers.

[6] See Borjas (2015) and the references therein. Our model could also be extended to allow for a substitution between apprentices and other types of unskilled or skilled labor in the firm. However, recent empirical evidence for Germany shows that apprentices are no direct substitute for other types of labor (Hinz 2019).

[7] Only a few training occupations have a very high within-occupation share of apprentices with a high school degree (e.g., bank clerk), indicating that applicants with high and low levels of education can indeed be considered substitutes across a wide range of occupations (Figure A2).

[8] See Appendix A for the derivations.

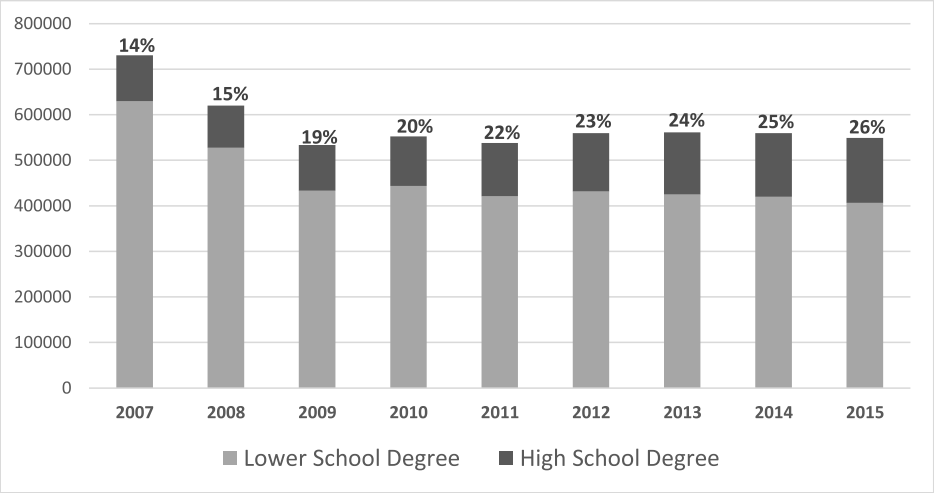

Figure 3. Applicants by educational qualification, 2007 to 2015
Source: BIBB Data Reports 2008–2016 (https://www.bibb.de/datenreport/). Lower secondary school degree contains both registered graduates of lower secondary schools and those without a secondary degree.

may cause wage rigidity. Firm-level institutions, such as collective bargaining or works councils, may lead to apprentice wages above the market-clearing level and thus prevent wage adjustments in response to productivity shocks. A wage reduction for apprentices in Germany due to one-time variations in the supply may also be perceived as unfair by works councils, unions, youth and trainee councils or equal opportunities officers. Moreover, firms may decide not to engage in time-consuming wage negotiations particularly because wages would need to be renegotiated again in the following year. Recent empirical evidence supports the notion of wage rigidity in the German labor market, pointing toward a zero elasticity of wage growth with respect to wages in economic downturns, but a positive wage elasticity during boom periods (Snell et al. 2018).

While collective bargaining agreements in Germany set binding apprentice wages at the industry level, they do not account for heterogeneity in an apprentice's education level. Thus, the collectively bargained wages may in fact be below the market-clearing level for the group of apprentices with a high school degree, as they are more productive because they have higher levels of cognitive and non-cognitive skills.[9] However, training firms may have monopsony power over high school apprentices due to mobility costs, as apprentices tend to be less mobile than other employees, and information asymmetries regarding the training quality (De la Croix et al. 2018, Muehlemann et al. 2013). Moreover, as argued in Ryan et al. (2013), informal employer coordination (e.g., through employer associations, training networks, youth and trainee councils, equal opportunities officers) may effectively prevent wage competition for highly qualified apprentices.

Even though apprentice pay in Germany is strictly regulated in firms bound by collective bargaining, firms have discretionary power to increase wages. A firm size wage premium is a stylized fact, at least for regular workers. In contrast, apprentices trained in small firms may not be covered by collective bargaining. To comply with the theoretical model, we will account for firm size in the empirical analysis. The marginal effects of apprentice pay will then be discussed.

A short-run analysis of the case for (downward) wage rigidity is particularly interesting because the implementation of the high school reform in different states takes place in one-year periods at different times. In sum, employer coordination not only occurs in the context of collective bargaining agreements, but may also help to keep wages of high school apprentices below the competitive wage level. Finally, because apprentices from the pre-reform cohort are one year older at the time of graduation, their marginal productivity may be lower. This implies that

$$w_{NA} < w_A^1 \leq w_A^0.$$

When wages are fixed and below the competitive level, *ceteris paribus*, then a firm would be willing to hire additional apprentices at wage $w_A^1 = w_A^0$ when a supply shock occurs. The supply of highly educated apprentices is absorbed entirely by firms, that decide to keep the input of x_{NA} as ($x_{NA}^1 = x_{NA}^0$) or will hold their total wage bill constant ($x_{NA}^1 < x_{NA}^0$). This implies that

$$x_{NA}^1 \leq x_{NA}^0 \text{ and } x_A^1 > x_A^0.$$

For the scenarios of unit elasticity, complements, and wage rigidity with or without substitutability of x_A and x_{NA} we can formulate the following relationships between employment and wages:

Unity of substitution between x_A and x_{NA}	Complementary input of x_A and x_{NA}	Wage rigidity
$x_{NA}^1 < x_{NA}^0;\ x_A^1 > x_A^0$	$x_{NA}^1 = x_{NA}^0;\ x_A^1 = x_A^0$	$x_{NA}^1 = x_{NA}^0;\ x_A^1 > x_A^0$
$w_{NA}^1 > w_{NA}^0;\ w_A^1 < w_A^0$	$w_{NA}^1 = w_{NA}^0;\ w_A^1 < w_A^0$	$w_{NA}^1 = w_{NA}^0;\ w_A^1 = w_A^0$

4. Data and variable construction

More than two-thirds of German youth graduate from lower secondary schools.[10] The dominant choice of most individuals is to apply

[9] We find a substantial within-occupation wage premium for high school apprentices, which amounts 13.2% higher wages in occupations with less than 25% high school apprentices, 8.2% higher wages in occupations with 25%-50% high school apprentices, and 9.2% higher wages in occupations with >50% high school apprentices. These figures are in line with our theoretical prediction that high school apprentices earn wages that are higher than the collectively bargained wage. Note that we do not have information about collective bargaining coverage in our firm-level data, thus we cannot directly test for wage differentials by educational qualification in firms with collective bargaining agreements.

[10] After primary school, usually at the age of 10, students continue their education in one of three secondary school types based on their performance in the primary schools. While lower secondary tracks (*Hauptschule* and *Realschule*) require another five to six years of school attendance after the first four years of elementary school, upper secondary high school entrants study another eight to nine years. The school types vary not only in terms of the number of schooling years but also in terms of the level of expected learning abilities (see also Wößmann 2016).

Table 1
Growth rate of the number of apprentices with a high school degree (by state), 2008–2015

Year	SH	HH	NI	HB	NW	HE	RP	BW	BY	SL	BE	BB	MV	SN	ST	TH
2008	-8%	-10%	-6%	4%	2%	-1%	3%	-8%	-2%	11%	-1%	3%	**21%**	4%	-13%	-3%
2009	10%	3%	-2%	-2%	-2%	-5%	-4%	2%	-13%	**1%**	-5%	-3%	-10%	-5%	-7%	-9%
2010	8%	**11%**	7%	3%	5%	7%	11%	9%	12%	-5%	2%	-10%	-13%	-12%	-12%	-3%
2011	16%	6%	**27%**	14%	8%	11%	12%	19%	**30%**	-4%	-3%	-8%	-5%	1%	-6%	-6%
2012	-2%	-2%	-6%	**-5%**	3%	3%	3%	**11%**	-3%	11%	**4%**	**-7%**	-12%	-7%	-15%	-10%
2013	1%	-2%	0%	-3%	**7%**	**0%**	0%	-3%	0%	-8%	-7%	-8%	-2%	-11%	-2%	-12%
2014	6%	1%	5%	-1%	-2%	**2%**	7%	7%	8%	5%	4%	-4%	0%	3%	-4%	1%
2015	12%	3%	5%	0%	4%	4%	7%	7%	10%	4%	4%	6%	5%	9%	1%	3%

Notes: The numbers in bold indicate the year in which a double cohort graduated from high school due to the reform. SH=Schleswig-Holstein, HH=Hamburg, NI=Lower Saxony, HB=Bremen, NW=North Rhine-Westphalia, HE=Hesse, RP=Rhineland-Palatinate, BW=Baden-Württemberg, BY=Bavaria, SL=Saarland, BE=Berlin, BB=Brandenburg, MV=Mecklenburg-Vorpommern, SN=Saxony, ST=Saxony-Anhalt, TH=Thuringia. Source: Vocational Education and Training statistics provided by the Federal Statistical Office and the statistical offices of the federal states.

Table 2
Average daily wage of new apprentices with a high school degree (in euros, by state), 2007–2015

Year	SH	HH	NI	HB	NW	HE	RP	BW	BY	SL	BE	BB	MV	SN	ST	TH
2007	21.3	23.4	21.5	21.2	22.2	23.5	22.1	24.6	22.9	22.0	21.8	17.6	17.3	17.6	17.6	16.9
2008	21.8	23.8	22.1	22.2	23.1	23.9	22.9	25.3	23.5	23.2	22.2	18.8	**18.3**	18.7	19.2	18.1
2009	22.0	24.0	22.6	22.0	23.4	24.3	23.4	25.6	23.7	**23.0**	22.5	19.7	19.6	19.4	19.9	18.3
2010	22.5	**24.2**	22.8	22.9	23.6	24.3	23.6	25.3	23.9	22.8	22.1	20.2	19.5	19.8	20.6	19.2
2011	22.5	24.5	**22.8**	22.7	23.6	24.7	23.0	25.2	**24.2**	22.9	22.1	21.0	20.2	19.5	21.5	20.3
2012	24.0	25.7	24.6	**23.9**	24.7	26.8	25.1	**28.6**	26.0	24.8	**24.6**	**22.5**	21.7	20.7	21.8	21.8
2013	24.3	25.6	25.5	24.8	**25.3**	**26.8**	25.2	28.2	26.2	25.2	24.5	23.4	21.9	21.9	22.7	22.7
2014	24.9	26.2	26.0	25.5	25.9	**27.4**	25.7	28.7	26.6	25.5	25.4	23.8	22.9	22.4	23.7	23.6
2015	25.5	26.9	26.5	25.6	26.4	27.8	26.3	29.1	27.5	26.0	25.8	24.2	23.6	23.2	24.4	24.5

Notes: The numbers in bold indicate the year in which a double cohort graduated from high school due to the reform. SH=Schleswig-Holstein, HH=Hamburg, NI=Lower Saxony, HB=Bremen, NW=North Rhine-Westphalia, HE=Hesse, RP=Rhineland-Palatinate, BW=Baden-Württemberg, BY=Bavaria, SL=Saarland, BE=Berlin, BB=Brandenburg, MV=Mecklenburg-Vorpommern, SN=Saxony, ST=Saxony-Anhalt, TH=Thuringia. Source: IEB employer–employee linked data. Total number of observations: N=348,734.

for an apprenticeship in the "dual system", which combines in-company training with part-time education in a vocational school. The typical starting age for an apprenticeship is between 16 and 20 years old. Overall, more than 500,000 new apprenticeship contracts are signed each year, and with most apprenticeships lasting three years, approximately 1.5 million young adults are enrolled in an apprenticeship at any given point in time (BIBB 2017a).

Although they have access to a university education, a significant share of high school graduates apply for an apprenticeship (BIBB 2017a). Figure 3 shows the number of high school applicants relative to the number of applicants with lower secondary school degrees between 2007 and 2017.[11] The share of applicants with a high school degree increased from approximately 14% in 2007 to 26% in 2015. This indicates that in comparison to other school graduates, high school graduates have become more prevalent in the apprenticeship market in recent years.

The data source for our empirical analysis is the universe of all new yearly apprenticeship contracts provided by the Federal Statistical Office. The data include training characteristics (e.g., of the contract holder) and regional and occupation-specific information. We construct an occupation-level panel data set that includes the number of new contracts in a given occupation, state, and year. We end up with 321 apprenticeship occupations for the 16 federal states over the period 2007 to 2015.

Second, our measure of the potential supply of apprentices is the number of graduates from high schools (having obtained upper secondary degrees) and of graduates from lower secondary schools. Statistics on the yearly number of school graduates are available from the Federal Statistical Office (Destatis 2016, 2019). Table 1 shows the growth rate of apprenticeship contracts per state from 2008 to 2015. Although it is not possible to quantify reform effects based on the descriptive information in the table, some states indeed show a clear increase in the growth rate of apprenticeship contracts with high school graduates in the year when a particular state was affected by the high school reform. Bavaria and Lower Saxony, for example, show an increase in apprenticeship contracts among individuals who have obtained a high school degree of almost 30% in the year when the reform affected high school graduation rates. However, some smaller states were likely affected by reform-induced graduation rates in neighboring states, as high school graduates may apply for out-of-state apprenticeships. Bremen, a small city-state, is fully surrounded by the much larger state of Lower Saxony. Thus, in the year when the double cohort in Lower Saxony graduated, the number of apprenticeships in Bremen increased sharply because many apprentices employed by firms located in Bremen reside in Lower Saxony. However, even in the year prior to the reform, approximately one-third of all apprentices in Bremen lived in Lower Saxony (Table A1). We can explain this observation by the fact that the population of Lower Saxony is more than ten times larger than that of the city-state of Bremen. To take into account such interrelations between neighboring states, we also analyze subsamples of states affected by the school reform in different years.[12] However, in general, we find that the vast majority of apprentices live and work in the same state, and that the reform did not increase cross-border mobility (Table A1).

Finally, we exploit two administrative data sets. First, the 100% sample of the Integrated Employment Biographies (IEB) of the Institute for Employment Research (IAB) (Antoni et al. 2019), which contains information on daily apprentice wages. This is the only representative data source in Germany that allows us to calculate apprentice wages at

[11] Note that applicants are defined as the sum of individuals who successfully signed an apprenticeship contract and unsuccessful applicants who registered with the Federal Employment Agency.

[12] We drop the state of Hesse from our analysis because double graduation from high school stretched over two years.

the occupation level in a particular state, and over time. Second, we use the establishment history panel (BHP; see Ganzer et al. 2021), which enables us to analyze the wage development of new apprentices at the firm level by linking the individual-level observations. Table 2 shows the development of daily apprentice wages in German states from 2007 to 2015. On average, apprentices with a high school degree earn 17 to 30 euros per day in their first year of training. Apprentice wages increased strongly over our observation period; however, the level of apprentice pay clearly differed by state. In particular, apprentice wages were substantially lower in East Germany at the beginning of our observation period, although East German apprentice wages caught up over time and reduced the gap with the western states substantially. While differences in apprentice wages across states can be due to regional heterogeneity in collective bargaining agreements, wages are also related to differences in economic activity across states and thus differences in the relative importance of particular training occupations.[13]

5. Identification strategy

In a first step, we apply difference-in-differences estimation techniques to identify the effect of the high school reform on the number of new apprenticeship contracts and the corresponding wages of new apprentices. Second, to assess whether the relationship between school leavers and apprenticeship contracts differs in a year when the number of graduates was affected by the school reform, we estimate the elasticity of the number of apprenticeship contracts (and apprentice wages) with respect to the number of school leavers with a high school and lower secondary school qualification. Finally, we use instrumental variable panel regressions and exploit the exogenous change in the supply of apprentices that was caused by the high school reform to identify the effect on the apprenticeship market. For each step and each regression, we provide overall results for Germany and separate results for West and East Germany. The reason for doing so is that even more than 30 years after reunification, training and labor markets are still shaped by stark differences between East and West Germany (Schnabel 2016).

5.1. Difference-in-differences estimation to identify the effects of the high school reform

We estimate the following fixed-effects panel model, where we denote the log number of new contracts of apprentices with a high school degree in occupation o in state s in year t as

$$a_{ost}^{HS} = \alpha_{os} + \lambda_t^{HS} + \theta^{HS} D_{st} + \gamma_o^{HS} t_o + \gamma_s^{HS} t_s + \epsilon_{ost}^{HS}$$

where the difference-in-differences estimator is θ^{HS}, as D_{st} is an indicator variable equal to 1 when graduation rates were affected by the school reform in year t and state s. Thus, θ^{HS} is an estimate of the average number of additional apprenticeship contracts signed because of the school reform across all German states.[14] Moreover, α_{os} controls for the fixed effects for occupation o in state s and accounts for the fact that the baseline shares of apprentices with a high school degree vary by training occupation and state. The year dummies λ_t^{HS} control for year-specific effects. The trend variable t_o at occupation level o controls for occupation-specific developments over time, and t_s controls for developments at the state level.[15] Thus, we assume that when accounting for all these factors, states other than those in which graduation rates were affected by the reform in a particular year t show comparable development (*common trends*) in the number of apprenticeship contracts. We also provide robustness checks by analyzing subsamples of neighboring states (e.g., Bavaria and Baden-Wurttemberg). In such states, it may be even more reasonable to assume that both economic development and general interest in the apprenticeship training of individuals and firms are more comparable than for states that differ more in their geographic proximity.

We estimate a similar regression for wages, but at the level of the firm to account for time-invariant unobserved heterogeneity, and in line with our theoretical model that makes predictions at the level of the firm.[16] We denote the log average daily apprentice wage of all new hires with a high school degree in firm i in year t as:

$$w_{it}^{HS} = \alpha_i + \lambda_t^{HS} + \theta^{HS} D_{st} + \beta X_{it} + \epsilon_{it}^{HS}$$

where α_i accounts for time-invariant unobserved characteristics of the firm, and X includes the number of employees and the medium wage of skilled employees, and the average age of newly hired apprentices.[17] Again, θ^{HS} measures the effect of the high school reform, but in this case its effect on apprentice wages rather than apprenticeship contracts.

5.2. Estimating the elasticity of apprenticeship contracts with respect to school graduates

While the difference-in-differences estimation yields the direct effect of the high school reform on the number of apprenticeship contracts and wages, we are also interested in analyzing the extent to which the number of high school graduates is associated with the number of apprenticeship contracts for individuals with a high school degree. As shown in Section 4, the share of apprentices with a high school degree has increased substantially in recent years. Thus, we estimate the elasticity of the number of apprenticeship contracts with respect to the number of high school graduates:

$$a_{ost}^{HS} = \alpha_{os} + \lambda_t^{HS} + \theta^{HS} graduates_{st} + \gamma_o^{HS} t_o + \gamma_s^{HS} t_s + \epsilon_{ost}^{HS},$$

where $graduates_{st}$ is defined as the log number of individuals who graduate from high school in year t and state s. Moreover, we include the same fixed effects and trend variables as in the difference-in-differences specification above.

Second, we estimate the association between the log of the average daily wage of newly hired apprentices with a high school degree at the

[13] The automotive industry, for example, is particularly important in Baden-Württemberg, Bavaria, and Lower Saxony, but much less important in many other states.

[14] We cluster standard errors at the level of the treatment (i.e., the state level).

[15] Jansen et al. (2017) estimate a model similar to this one in the context of curriculum reforms in the German apprenticeship market.

[16] Dorner and Görlitz (2020) estimate a similar model, although their main motivation in their paper is on the effect of a missing cohort of high school graduates in two East German states that extended the duration of high school from 12 to 13 years, so that in 2001 there were no high school graduates in these two states. In addition, they also report results that includes the more recent high school reform, which is the focus of our paper. Their analysis, however, is based on individual wage data that includes a firm identifier variable to account for unobserved firm heterogeneity, and they do not differentiate wages by the education level of an apprentices (except for including a dummy variable for the level of education, for which they do not report coefficient estimates). Conversely, we run our regressions at the firm-level, and focus on changes in the average wage of new apprentices in the training firm that is associated with the positive supply shock that was caused by the high school reform. Note that we excluded firms that moved between states during our period of observation.

[17] We also estimated individual level wage regressions that include the age, gender, and migration background of an apprentice as controls, and a model that includes the firm-identifier to account for unobserved heterogeneity at the firm level. Moreover, we estimated a model based on average wages at the 3-digit occupation level for each state, similarly to the specification above for apprenticeship contracts. All results are qualitatively in line with our fixed-effects regressions at the level of the firm, and we did not find evidence that the high school reform led to a statistically significant reduction in the wage of apprentices with a high school degree.

Table 3
Effects of the high school reform on the number of apprenticeship contracts among high school graduates

	Model 1	Model 2	Model 3	West Germany	East Germany
High school reform	0.125**	0.124**	0.070***	0.066***	0.097***
	(0.044)	(0.045)	(0.020)	(0.0167)	(0.043)
Year dummies	Yes	Yes	Yes	Yes	Yes
Occupational trends	No	Yes	Yes	Yes	Yes
State-level trends	No	No	Yes	Yes	Yes
State-level occupation FE	Yes	Yes	Yes	Yes	Yes
Constant	4.415***	4.317***	4.229***	4.519***	4.013***
	(0.039)	(0.058)	(0.026)	(0.023)	(0.023)
Observations	23470	23470	23470	16237	7233
R^2	0.021	0.201	0.382	0.413	0.427

Notes: Dependent variable: ln (number of new apprenticeship contracts at occupation level) of high school graduates. Clustered standard errors are in parentheses. *** Significant at the 1% level; ** significant at the 5% level; * significant at the 10% level. Weighted regressions, using number of apprentices per occupation and state as weights. Source: Vocational Education and Training statistics provided by the Federal Statistical Office and the statistical offices of the federal states.

Table 4
Effects of the high school reform on the number of apprenticeship contracts among lower secondary school graduates

	Model 1	Model 2	Model 3	West Germany	East Germany
High school reform	0.021	0.021	0.006	0.005	0.004
	(0.017)	(0.017)	(0.013)	(0.014)	(0.022)
Year dummies	Yes	Yes	Yes	Yes	Yes
Occupational trends	No	Yes	Yes	Yes	Yes
State-level trends	No	No	Yes	Yes	Yes
State-level occupation FE	Yes	Yes	Yes	Yes	Yes
Constant	4.923***	4.850***	4.832***	5.067***	4.456***
	(0.024)	(0.029)	(0.019)	(0.021)	(0.051)
Observations	22213	22213	22213	15433	6780
R^2	0.145	0.292	0.321	0.366	0.407

Notes: Dependent variable: ln (number of new apprenticeship contracts at occupation level) of lower secondary school graduates. Standard errors are in parentheses. *** Significant at the 1% level; ** significant at the 5% level; * significant at the 10% level. Weighted regressions, using number of apprentices per occupation and state as weights. Source: Vocational Education and Training statistics provided by the Federal Statistical Office and the statistical offices of the federal states.

firm level and the number of high school graduates at the state level:

$$w_{it}^{HS} = \alpha_i + \lambda_t^{HS} + \theta^{HS} graduates_{st} + \beta X_{it} + \epsilon_{it}^{HS}$$

The control variables are identical to the specification of the firm-level wage regression in the previous section.

5.3. Instrumental variable estimation

Finally, we estimate the association between high school graduates and the number of apprenticeship contracts (and apprentice wages) in the year in which the high school reform led to an increase in high school graduation rates. We use the high school reform as an instrument for the number of graduates, as the reform itself constitutes plausibly exogenous variation in the number of high school graduates. The school reform is a valid instrument to the extent that its implementation date (in period $t-8$) is independent of the number of apprenticeship contracts in period t. Further, as the school reform was unrelated to any issues in the vocational education and training system, and thus the development of apprenticeship contracts, it constitutes a valid instrument. Moreover, the timing of the implementation can be considered as good as random, because political processes in some states may require more time for reasons unrelated to current developments in the apprenticeship market. Thus, we can interpret the results as a local average treatment effect: we identify the extent to which the number of apprenticeship contracts and apprentice wages are affected by the reform-induced change in the number of high school graduates.

6. Results

In this section, we first report our difference-in-differences estimates and then discuss the results from our panel fixed-effects and instrumental variable panel fixed-effects regressions to identify the association between the number of high school graduates and our dependent variables of interest. Finally, we report robustness checks and test for anticipation effects of the high school reform.

6.1. Difference-in-differences estimates

As expected, the positive supply shock led to an increase in apprenticeship contracts for individuals with a high school degree. For Germany as a whole, the high school reform raised the number of apprenticeship contracts by 7%. The effect was somewhat lower in West Germany (6.6%) and higher in East Germany (9.7%), as reported in Table 3. However, the positive supply shock of high school graduates had no negative effect on the number of apprenticeship contracts among individuals with lower secondary school degrees, as reported in Table 4. Thus, these results are not in line with the predictions of our theoretical model that assumes that apprentices with different education levels are substitutes in the production process.[18]

To allow for heterogeneity of the reform effects across occupations that differ in terms of the share of apprentices with a high school degree, we carried out some additional regressions. We find that both in West and East Germany, the high school reform led to a stronger increase in the number of apprenticeship contracts in occupations that had a relatively low share of apprentices with a high school degree prior to the reform (Table A2). However, we do not find any wage effects even within occupations with a low share of apprentices with a high school degree prior to the reform (Table A3).

With regard to apprenticeship wages, we expect a negative effect of the high school reform if markets are competitive. However, our firm-level panel fixed-effects estimates show no evidence of any negative wage effects due to the high school reform, neither for apprentices with a high school degree (Table 5), nor for apprentices with a lower secondary school degree. We also estimated regressions for subsamples of firms in West and East Germany, as well as by firm size. While some point coefficients are negative, particularly in East Germany, the economic magnitude is very small (a wage reduction of less than 0.1% on average) and the coefficients are imprecisely estimated despite the large number of observations in our data. We also estimate a model to test

[18] Ideally, we would use firm-level data to test for substitution effects. However, the majority of German training firms do not hire more than one apprentice in a particular occupation per year. Thus, an alternative would be to focus on larger firms that hire more apprentices with different educational backgrounds in the same training occupation; however, this could potentially introduce a selection bias. Nonetheless, we also estimate a firm-level fixed effects panel regression, and we find that the high school reform increased the number of apprenticeships with high school graduates by about 9%. Conversely, we find only a small positive effect of less than 1% for non-high school apprentices (Table A6).

Table 5
Effects of the high school reform on the apprentice wages of high school graduates

	Full sample	West Germany				East Germany			
		All	500+	50-499	<50	All	500+	50-499	<50
High school reform	0.000 (0.004)	0.003 (0.004)	0.002 (0.005)	0.004 (0.004)	0.002 (0.005)	-0.009	-0.001	-0.008	-0.010
						(0.006)	(0.009)	(0.008)	(0.006)
ln (employees)	0.007*	0.006 (0.003)	0.054***	0.013*	0.003 (0.002)	0.008 (0.004)	0.023 (0.015)	0.037*	-0.007
	(0.002)		(0.010)	(0.004)				(0.010)	(0.009)
Median skilled worker wage	0.001***	0.001***	0.001***	0.001***	0.000**	0.000**	0.001 (0.001)	0.001***	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)		(0.000)	(0.000)
Average age of apprentice	0.004***	0.004***	0.007***	0.004***	0.003***	0.004**	0.004 (0.004)	0.004*	0.004*
	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)		(0.001)	(0.001)
Constant	2.807***	2.838***	2.599***	2.836***	2.792***	2.614***	2.752***	2.515***	2.563***
	(0.020)	(0.023)	(0.082)	(0.031)	(0.018)	(0.040)	(0.126)	(0.082)	(0.023)
Observations	348734	301092	21149	122873	157070	47642	2922	19285	25435
R^2	0.286	0.278	0.389	0.301	0.220	0.356	0.439	0.366	0.332

Notes: Dependent variable: ln (average wage of newly hired apprentices with a high school degree at firm level). Clustered standard errors are in parentheses. *** Significant at the 0.1% level; ** significant at the 1% level; * significant at the 5% level. Sources: IEB, IAB-BHP, KMK.

Table 6
Effects of the high school reform on the apprentice wages of lower secondary school graduates

	Full sample	West Germany				East Germany			
		All	500+	50-499	<50	All	500+	50-499	<50
High school reform	-0.005 (0.002)	-0.003	0.002	-0.004	-0.003	-0.008	-0.009	-0.009	-0.006
		(0.003)	(0.003)	(0.002)	(0.003)	(0.007)	(0.008)	(0.009)	(0.006)
ln (employees)	0.002 (0.001)	0.002	0.027*	0.015***	-0.002	0.008*	-0.002	0.034*	0.003
		(0.001)	(0.010)	(0.003)	(0.001)	(0.002)	(0.023)	(0.009)	(0.004)
Median skilled worker wage	0.001***	0.000***	0.001***	0.001***	0.000***	0.001***	0.001**	0.002***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Average age of apprentice	0.004***(0.001)	0.004***	0.003	0.006***	0.004***	0.002*	0.001	0.002	0.002
		(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.003)	(0.002)	(0.001)
Constant	2.651***(0.014)	2.683***	2.797***	2.685***	2.653***	2.391***	2.865***	2.388***	2.348***
		(0.017)	(0.094)	(0.025)	(0.017)	(0.012)	(0.149)	(0.056)	(0.020)
Observations	1570276	1364539	27498	280311	1056730	205737	3809	52241	149687
R^2	0.239	0.228	0.452	0.269	0.215	0.323	0.479	0.377	0.293

Notes: Dependent variable: ln (average wage of newly hired apprentice with a lower secondary school degree at firm level). Clustered standard errors are in parentheses. *** Significant at the 0.1% level; ** significant at the 1% level; * significant at the 5% level. *Sources:* IEB, IAB-BHP, KMK.

Table 7
Elasticity of apprenticeship contracts with respect to high school graduates: Panel fixed-effects regression

	Model 1	Model 2	West Germany	East Germany
ln(graduates HS)	0.410***	0.194***	0.149***	0.200*
	(0.040)	(0.029)	(0.021)	(0.045)
Year dummies	Yes	Yes	Yes	Yes
Occupational trends	No	Yes	Yes	Yes
State-level trends	No	Yes	Yes	Yes
State and occupation FE	Yes	Yes	Yes	Yes
Constant	0.583	2.488***	3.125**	2.180***
	(0.373)	(0.258)	(0.193)	(0.413)
Observations	23470	23470	16237	7233
R^2	0.111	0.387	0.415	0.428

Notes: Dependent variable: ln (number of new apprenticeship contracts at occupation level) of high school graduates. Clustered standard errors are in parentheses. *** Significant at the 0.1% level; ** significant at the 1% level; * significant at the 5% level. Weighted regressions, using number of apprentices per occupation and state as weights. Source: Vocational Education and Training statistics provided by the Federal Statistical Office and the statistical offices of the federal states.

whether firms that trained apprentices in the year prior to the school reform offered an apprentice wage that differs from firms that did not train any apprentices prior to the reform. However, we find no statistically significant effects. Similarly, we find no wage effects due to the reform when estimating a panel fixed-effects regression model at the occupational level.[19] Thus, our results suggest that the institutional setting of the German apprenticeship system prevents firms from adjusting wages downward. While no formal rules prevent training firms from increasing their wage offers when facing a shortage in supply to the market-clearing level, employer coordination may prevent wage competition informally (Ryan et al. 2013).

In comparison to Dorner and Goerlitz (2020), our results highlight that it is important to account for heterogenous effects by estimating separate subsamples for East and West Germany, and for apprentices with and without a high school qualification. While Dorner and Goerlitz (2020) find an overall negative effect of the high school reform in the magnitude of -0.6% on average wages, we find that the reform had no statistically significant effect on wages of apprentices with a high school qualification in West Germany. We find a negative point estimate of -0.009 for apprentices with a high school qualification in East Germany,

[19] Results are available upon request.

Table 8
Elasticity of apprentice wages with respect to high school graduates: Panel fixed-effects regression

	Full sample	West Germany				East Germany			
		All	500+	50-499	<50	All	500+	50-499	<50
ln (number of high school graduates)	-0.025	0.005	0.001	0.008	0.004	-0.038*	-0.010	-0.039	-0.038**
	(0.012)	(0.009)	(0.009)	(0.008)	(0.010)	(0.015)	(0.013)	(0.024)	(0.007)
ln (number of employees)	0.006*	0.006	0.054***	0.014*	0.003	0.008	0.022	0.036*	-0.007
	(0.002)	(0.003)	(0.010)	(0.004)	(0.002)	(0.004)	(0.014)	(0.011)	(0.009)
Median skilled worker wage	0.001***	0.001***	0.001***	0.001***	0.000**	0.000**	0.001	0.001***	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)
Average age of apprentice	0.004***	0.004***	0.007***	0.004***	0.003***	0.004**	0.004	0.003	0.004*
	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.004)	(0.001)	(0.001)
Constant	3.057***	2.782***	2.591***	2.759***	2.754***	2.973***	2.852***	2.886***	2.916***
	(0.130)	(0.109)	(0.079)	(0.101)	(0.119)	(0.170)	(0.199)	(0.293)	(0.080)
Observations	348734	301092	21149	122873	157070	47642	2922	19285	25435
R^2	0.288	0.278	0.389	0.301	0.220	0.357	0.439	0.367	0.333

Notes: Dependent variable: ln (average wage of newly hired apprentice with a high school degree at firm level). Clustered standard errors are in parentheses. *** Significant at the 0.1% level; ** significant at the 1% level; * significant at the 5% level. *Sources:* IEB, IAB-BHP, KMK.

Table 9
Elasticity of apprenticeship contracts with respect to high school graduates: Instrumental variable panel fixed-effects regression

	First stage: ln(graduates HS)			Second stage: ln(apprenticeship contracts)			
	Full sample	West Germany	East Germany	Model 1	Model 2	West Germany	East Germany
High school reform	0.500***	0.506***	0.472***				
	(0.039)	(0.037)	(0.080)				
ln(graduates HS)				0.201***	0.139***	0.130***	0.206***
				(0.048)	(0.0317)	(0.025)	(0.051)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Occupational trends	Yes	Yes	Yes	No	Yes	Yes	Yes
State-level trends	Yes	Yes	Yes	No	Yes	Yes	Yes
State and occupation FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	23470	16237	7233	23470	23470	16237	7233

Notes: Dependent variable: ln (number of new apprenticeship contracts at occupation level) of high school graduates. Clustered standard errors are in parentheses. *** Significant at the 0.1% level; ** significant at the 1% level; * significant at the 5% level. Weighted regressions, using number of apprentices per occupation and state as weights. Source: Vocational Education and Training statistics provided by the Federal Statistical Office and the statistical offices of the federal states.

Table 10
Elasticity of apprentice wages with respect to high school graduates: Instrumental variable panel fixed-effects regression

	Full sample	West Germany				East Germany			
		All	500+	50-499	<50	All	500+	50-499	<50
ln (number of high school graduates)	0.000	0.007	0.004	0.009	0.004	-0.016*	-0.002	-0.014	-0.017*
	(0.008)	(0.008)	(0.010)	(0.007)	(0.010)	(0.008)	(0.015)	(0.012)	(0.009)
ln (number of employees)	0.007**	0.006*	0.054***	0.014***	0.003	0.008*	0.023	0.037***	-0.007
	(0.002)	(0.003)	(0.010)	(0.004)	(0.002)	(0.004)	(0.013)	(0.009)	(0.008)
Median skilled worker wage	0.001***	0.001***	0.001***	0.001***	0.000***	0.000***	0.001	0.001***	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Average age of apprentice	0.004***	0.004***	0.007***	0.004***	0.003***	0.004***	0.004	0.004**	0.004***
	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.003)	(0.001)	(0.001)
Observations	348734	301092	21149	122873	157070	47642	2922	19285	25435
R^2	0.286	0.278	0.388	0.301	0.220	0.357	0.439	0.366	0.332

Notes: Dependent variable: ln (average wage of newly hired apprentice with a high school degree at firm level). Instrument: Dummy variable indicating the year when the high school led to the graduation of a double cohort in year t and state s. Clustered standard errors are in parentheses. *** Significant at the 0.1% level; ** significant at the 1% level; * significant at the 5% level. *Sources:* IEB, IAB-BHP, KMK.

which is even slightly larger compared to the one reported in Dorner and Goerlitz, but it is not statistically significant. Moreover, given that the high school reform increased the number of apprenticeships for individuals with a high school qualification by almost 10% in East Germany (Table 3), a wage decrease of 0.09% corresponds to a wage elasticity of 0.09, which is economically speaking very small.

6.2. Elasticity of apprenticeship contracts and wages with respect to graduates

In general, we expect markets to react to changes in supply. Indeed, our empirical results show that an increase in the number of high school graduates is positively associated with the number of new apprenticeship contracts. Table 7 shows that a 1% increase in the number of high school graduates is associated with an increase in the number of apprenticeship contracts of 0.15% in West Germany and 0.2% in East Germany. Our elasticity estimate is lower compared to Maier and

Table 11
Effect of the high school reform on apprenticeship contracts: Subsamples and panel fixed-effects regression

	BY & BW	BY & NW	BY & NI	BW & NW	BW & RP	BW & SL
High school reform	0.063***	0.069***	0.077***	0.104**	0.110***	0.184**
	(0.012)	(0.010)	(0.012)	(0.017)	(0.01)	(0.001)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Occupational trends	Yes	Yes	Yes	Yes	Yes	Yes
State-level trends	Yes	Yes	Yes	Yes	Yes	Yes
State-level occupation FE	Yes	Yes	Yes	Yes	Yes	Yes
Constant	5.176***	5.792***	5.175***	5.753**	4.730**	4.430***
	(0.017)	(0.041)	(0.018)	(0.022)	(0.016)	(0.036)
Observations	3893	4268	3809	4247	3478	3089
R-squared	0.600	0.680	0.669	0.571	0.545	0.372

Notes: Dependent variable: ln (number of new apprenticeship contracts at occupation level) of high school graduates. Robust standard errors are in parentheses. Weighted regressions, using number of apprentices per occupation and state as weights. BW=Baden-Württemberg, BY=Bavaria, NI=Lower Saxony, HB=Bremen, NW=North Rhine-Westphalia, RP=Rhineland-Palatinate, SL=Saarland. *** Significant at the 0.1% level; ** significant at the 1% level; * significant at the 5% level. Source: Vocational Education and Training statistics provided by the Federal Statistical Office and the statistical offices of the federal states.

Table 12
Placebo test: Anticipation effects of the high school reform on the number of contracts

	Model 1	Model 2	Model 3	West Germany	East Germany
High school reform$_{t+1}$	0.0209	0.0196	-0.00732	-0.004	-0.0214
	(0.024)	(0.023)	(0.005)	(0.005)	(0.027)
Year dummies	Yes	Yes	Yes	Yes	Yes
Occupational-level trends	No	Yes	Yes	Yes	Yes
State-level trends	No	No	Yes	Yes	Yes
State-level occupation FE	Yes	Yes	Yes	Yes	Yes
Constant	5.592***	5.498***	5.398***	5.736***	5.001***
	(0.029)	(0.043)	(0.025)	(0.024)	(0.040)
Observations	23470	23470	23470	16237	7233
R-squared	0.098	0.359	0.437	0.390	0.555

Notes: Dependent variable: ln (number of new apprenticeship contracts at occupation level). Clustered standard errors are in parentheses. *** Significant at the 1% level; ** significant at the 5% level; * significant at the 10% level. Weighted regressions, using number of apprentices per occupation and state as weights. Source: Vocational Education and Training statistics provided by the Federal Statistical Office and the statistical offices of the federal states.

Walden (2014), who report an elasticity of 0.60 based on a state-level analysis between 1983 and 2003 for West German states. However, it is in line with the results of Baldi et al. (2014), who estimate an elasticity of 0.22 for the period 1999–2012.[20]

Turning to apprentice wages, our results show no statistically significant relationship between the number of high school graduates and the wages of apprentices with a high school degree in West Germany (Table 8). However, for East Germany the point estimates are statistically significant, but their economic significance is very low, as the coefficients indicate an elasticity of merely -0.04.[21]

In the next subsection, we explicitly test whether the reform-induced increase in the supply of apprentices had a statistically significant effect on the number of apprenticeship contracts among and wages of apprentices with a high school degree.

6.3. Instrumental variable estimation

Our first-stage estimates in Table 9 clearly show the strength of the effect of the high school reform on the number of high school graduates. On average, the high school reform increased the number of high school graduates by exp(0.5), or approximately 65%. The second-stage results are similar to those reported in Table 7. In West Germany, a 1% increase in the supply of high school graduates is associated with a 0.13% increase in the number of apprenticeship contracts among individuals with a high school degree (Table 9). These results suggest that firms absorbed the increase in the supply of apprentices with a high school degree in a way similar to that of other years, despite the marked reform-induced increase in graduation rates.

Moreover, Table 10 also confirms the results of our panel fixed effects estimates in Table 6, as we find no empirical evidence that the high school reform-induced increase in the supply of high school graduates affected apprentice wages in West Germany, while we find a small (a wage elasticity of -0.016) and only marginally statistically significant wage effect for East Germany. Thus, as is the case in regular years, our results suggest that the growth in apprentice wages for individuals with a high school degree is predominantly driven by factors other than the supply of high school graduates. In summary, our empirical evidence suggests that $x^1_{NA} = x^0_{NA}$ and $x^1_A > x^0_A$, while $w^1_{NA} = w^0_{NA}$ and $w^1_A = w^0_A$, which supports the notion of sticky wages in the market for apprentices with a high school degree.

6.4. Robustness checks

We further analyze subsamples and consider different pairs of German states affected by the high school reform in different years to check whether our results are robust to a comparison of neighboring states that share a similar economic structure (e.g., Bavaria and Baden-Wuerttemberg) or non-bordering states in which few apprentices are expected to move across state borders in the control state, as the distance is too far (e.g., Bavaria and North Rhine-Westphalia). Table 11 shows that the results based on these subsamples broadly confirm the previous results based on the full sample, where we found an average reform-induced increase of 7% in West Germany, although some of the point

[20] Note that our empirical approach differs from Maier and Walden (2014) and Baldi et al. (2014), as we observe the number of apprenticeship contracts also at the occupation level and separately for high school and lower secondary school graduates, while they observe the total number of apprenticeship contracts at the state level.

[21] We estimated the models reported in Table 7 and Table 8 also for apprentices with a lower secondary school degree. The results are similar, as we find a positive association between school graduates and the number of contracts, and a small statistically significant association between school graduates and apprentice wages for firms in East Germany (Tables A4 and A5).

estimates (e.g., for BW & NW, BW & RP, and BW& SL) tend to be somewhat higher.

We further check whether there were any anticipation effects of reform-induced increases in graduation rates. Clearly, firms were aware that graduation rates would increase in a particular year, and thus, they could have altered their training behavior in the year before the supply shock.

However, the results in Table 12 show no statistically significant anticipation effects of the high school reform, which is consistent with firms not changing their training behavior prior to the reform.[22] We also estimated the same regression models for the subgroup of apprenticeship contracts with high school graduates, and none of the coefficients turned out to be statistically significant.[23]

7. Discussion

When a positive supply shock occurs in a competitive market, the equilibrium wage falls, and the number of contracts increases. In Germany, such an adjustment could not be observed in response to a strong one-time supply shock that was the result of school reform. While we identified an increase in the number of apprenticeship contracts with individuals holding a high school degree, we found no empirical evidence for substitution effects (i.e., no reduction in the number of apprentices with a lower school degree). Our results support the notion that the market for apprentices with a high education level is characterized by downward wage rigidity. Moreover, the association between wages and changes in the number of school graduates due to demographic change is very low for both high school and non-high school apprentices, and only marginally significant for non-high school apprentices in East Germany. Thus, wage rigidity is not limited to the one-time positive supply shock due to the high school reform and is particularly pronounced in West Germany. Contrasting the results of the missing cohort of school graduates reported in Dorner and Goerlitz (2020), however, provides some additional insight into the functioning of the German apprenticeship market. They find that a one-time negative supply shock was associated with a 1% increase in apprentice wages. Given that the reduction in apprenticeship contracts in two East German states was large (about -10%), the corresponding wage adjustment is still rather small (i.e., a wage elasticity of -0.1). In sum, the empirical results suggest that apprentice wages in West Germany are largely unrelated to changes in the supply of apprentices. Conversely, the market for apprentices in East Germany is somewhat responsive to changes in the supply of apprentices with and without a high school degree (Table 10, Table A5). These findings could be explained by the lower collective bargaining coverage in East Germany. Nonetheless, the point estimates of the wage effects remain very small in terms of their economic magnitude, as we find wage elasticities ranging from -0.01 to -0.07.

Although wages are sticky in the short run, firms may in turn find other ways to increase the attractiveness of apprenticeships for high school graduates (Göggel and Zwick, 2012). For example, more firms are starting to offer a combination of apprenticeships and university studies at the bachelor level. This "dual study" contract, demanding as it may be for high school apprentices, implies that apprentices spend less time in the firm and can allocate more time to their studies. Such a setting implicitly increases the hourly wage. Furthermore, regulations provide the option for high school graduates to shorten their training period by up to one year before signing the training contract. Apprentices then enter the second year of training straight away, receive a potentially higher starting wage and thus increase their individual rate of return to education.

Our results also have implications for future supply shocks in the apprenticeship market. As firms seem to be unable to adjust wages downwards in the short run, supply shocks such as the recent wave of migrants in 2015 may lead to the transitional unemployment of applicants for apprenticeships or a strong increase in individuals in the transitory system. Such a scenario is particularly relevant for migrants with lower secondary schooling degrees who often have below-average cognitive skills (particularly a lack of language skills). Thus, in contrast to highly educated apprentices, firms may not be willing to hire additional apprentices without a significant wage reduction. As a result, corresponding supply shocks would not be absorbed by the apprenticeship market, which is in line with the observation that in each year of our observation period, between 200,000 and 300,000 individuals (a large majority of them with a low schooling degree) were not successful in securing an apprenticeship contract and instead ended up in transitory vocational programs (BIBB 2017a).

8. Conclusion

Recent trends towards academization are visible in many countries, with an increasing share of individuals enrolling in colleges and universities. However, we find that in recent years, apprenticeships have increased in popularity among German high school graduates, even though such students could directly access a university education through their degree. This study analyzed the working of the market for highly educated apprentices. Specifically, it studied the effects of a recent school reform in Germany that led to a positive one-time supply shock of highly educated school graduates in the apprenticeship training market. Our results reveal important heterogeneity regarding the educational qualification of apprentices (high school vs. non-high school) even within the same training occupation. We find that firms contracted withmore apprentices with a high school degree without reducing the demand for lower secondary school graduates. Contrary to the prediction of theory under the assumptions of competitive markets, however, training firms absorbed the increased supply of highly educated apprentices without a significant reduction in apprentice wages. These findings support the existence of downward wage rigidity for high school apprentices in the German apprenticeship market. While wage stickiness may be associated with institutional factors such as collective bargaining agreements or works councils, our results are in line with the notion that informal employer coordination leads to a substantial within-occupation wage premium for high school apprentices, who are not only better educated but also older on average compared to non-high school apprentices. Thus, while collective bargaining agreements set a lower bound for apprentice wages, we find that high school apprentices earn a substantial within-occupation wage premium. However, our empirical evidence suggests that wages for both types of apprentices are rigid, as there is little cyclicality over time in response to changes in the supply of apprentices. Moreover, our results imply that training firms are willing to hire more high school apprentices at current wage levels. Thus, even though the share of high school apprentices increased steadily in recent years, there may be room for policies to make an apprenticeship education a more attractive educational option for high school graduates compared to the academic track, which is heavily subsidized in Germany so that tuition fees are very low (e.g., compared to the United States). Given that wage rigidity co-exists

[22] We acknowledge that analyzing anticipation behavior of firms would ideally require direct data on a firm's expectation about how the high school reform would affect the cost and benefits of apprenticeship training. However, as such data are not available, we resort to the aggregated number of training places at the occupation-state level as a proxy to test whether there was a substantial decrease in the number apprenticeship contracts prior to the reform.

[23] Moreover, to test whether firms reduce non-regular wage components that are not reflected in the reported daily wages, we analyze cross sectional firm-level data providing information on bonus payments for the year 2012 (BIBB CBS 2012, see Schönfeld et al. 2015). Only 14% of the training firms pay a bonus to apprentices and regression results show that neither a firm's likelihood of paying a bonus, nor the level of the bonus payment significantly differs in states with a double cohort compared to states without a double cohort in the year 2012.

in the German labor market, however, policies aimed at only undoing sticky wages for apprentices might be a double-edged sword, because frictions in the market for skilled workers may in part be the reason why German firms are willing to invest financial resources to train apprentices in the first place. However, a promising avenue for policy measures would be to make apprenticeship training a more attractive option compared to purely academic educational tracks. In recent years, dual studies, which combine vocational training in the workplace with academic education at the tertiary level and lead to a vocational qualification and an academic degree within a relatively short period, has become increasingly popular in Germany. Thus, policies supporting such educational options could potentially have significant benefits in terms of ensuring a highly skilled workforce that matches a firm's future skills demands.

Declaration of Competing Interest

We have no competing interests to report.

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Appendix A

Apprenticeship output y is produced according to a CES technology$y = (\alpha x_A^{\rho} + (1-\alpha)x_{NA}^{\rho})^{\frac{1}{\rho}}$, where $0 < \alpha < 1$ is the constant share parameter and $-\infty < \rho \leq 1$ determines the degree of substitutability between x_A and x_{NA}. The marginal costs of apprentices are fixed and differ between the two types of apprenticeships, with $w_A \geq w_{NA} > 0$. In the short run, output $\bar{y}$ is constant. Firms minimize their expected training costs $w_A x_A + w_{NA} x_{NA}$ subject to $\bar{y}$.

The Lagrangian function for this problem is

$$\mathscr{L}(x_A, x_{NA}, \lambda w_A, w_{NA}, \bar{y}) = w_A x_A + w_{NA} x_{NA} + \lambda\left(\bar{y} - \left(\alpha x_A^{\rho} + (1-\alpha)x_{NA}^{\rho}\right)^{\frac{1}{\rho}}\right) \tag{A1}$$

The first-order conditions are $\mathscr{L}_A = \frac{\partial \mathscr{L}}{\partial x_A} = 0$, $\mathscr{L}_{NA} = \frac{\partial \mathscr{L}}{\partial x_{NA}} = 0$, and $\mathscr{L}_{\lambda} = \frac{\partial \mathscr{L}}{\partial \lambda} = 0$. The first two conditions show that at the point of equilibrium, the isoquant curve is tangent to the isocost line

$$\frac{w_A}{w_{NA}} = \frac{\alpha}{1-\alpha}\left(\frac{x_A}{x_{NA}}\right)^{\rho-1} \tag{A2}$$

The point of tangency determines the equilibrium inputs x_A^* and x_{NA}^* at output level $\bar{y}$. Rewrite A2 in terms of x_A and x_{NA}. Substituting into $\mathscr{L}_{\lambda}$ obtains the short-run demand functions for the two types of apprenticeships:

$$x_A^*(w_A, w_{NA}, \bar{y}) = \frac{\bar{y}\left(\frac{w_A}{\alpha}\right)^{\frac{1}{\rho-1}}}{\left(\alpha\left(\frac{w_A}{\alpha}\right)^{\frac{\rho}{\rho-1}} + (1-\alpha)\left(\frac{w_{NA}}{1-\alpha}\right)^{\frac{\rho}{\rho-1}}\right)^{\frac{1}{\rho}}} \tag{A3i}$$

and

$$x_{NA}^*(w_A, w_{NA}, \bar{y}) = \frac{\bar{y}\left(\frac{w_{NA}}{1-\alpha}\right)^{\frac{1}{\rho-1}}}{\left(\alpha\left(\frac{w_A}{\alpha}\right)^{\frac{\rho}{\rho-1}} + (1-\alpha)\left(\frac{w_{NA}}{1-\alpha}\right)^{\frac{\rho}{\rho-1}}\right)^{\frac{1}{\rho}}}. \tag{A3ii}$$

The cost function is $c(w_A, w_{NA}, y) = w_A x_A^*(w_A, w_{NA}, y) + w_{NA} x_{NA}^*(w_A, w_{NA}, y)$.

Define $\gamma \equiv \left(\alpha\left(\frac{w_A}{\alpha}\right)^{\frac{\rho}{\rho-1}} + (1-\alpha)\left(\frac{w_{NA}}{1-\alpha}\right)^{\frac{\rho}{\rho-1}}\right)^{-\frac{1}{\rho}}$. Now, it is straightforward to show that the marginal and average costs are the same and do not depend on the level of output:

$$\frac{c(w_A, w_{NA}, y)}{y} = \frac{\partial c(w_A, w_{NA}, y)}{\partial y} = \gamma\left(w_A\left(\frac{w_A}{\alpha}\right)^{\frac{1}{\rho-1}} + w_{NA}\left(\frac{w_{NA}}{1-\alpha}\right)^{\frac{1}{\rho-1}}\right)$$

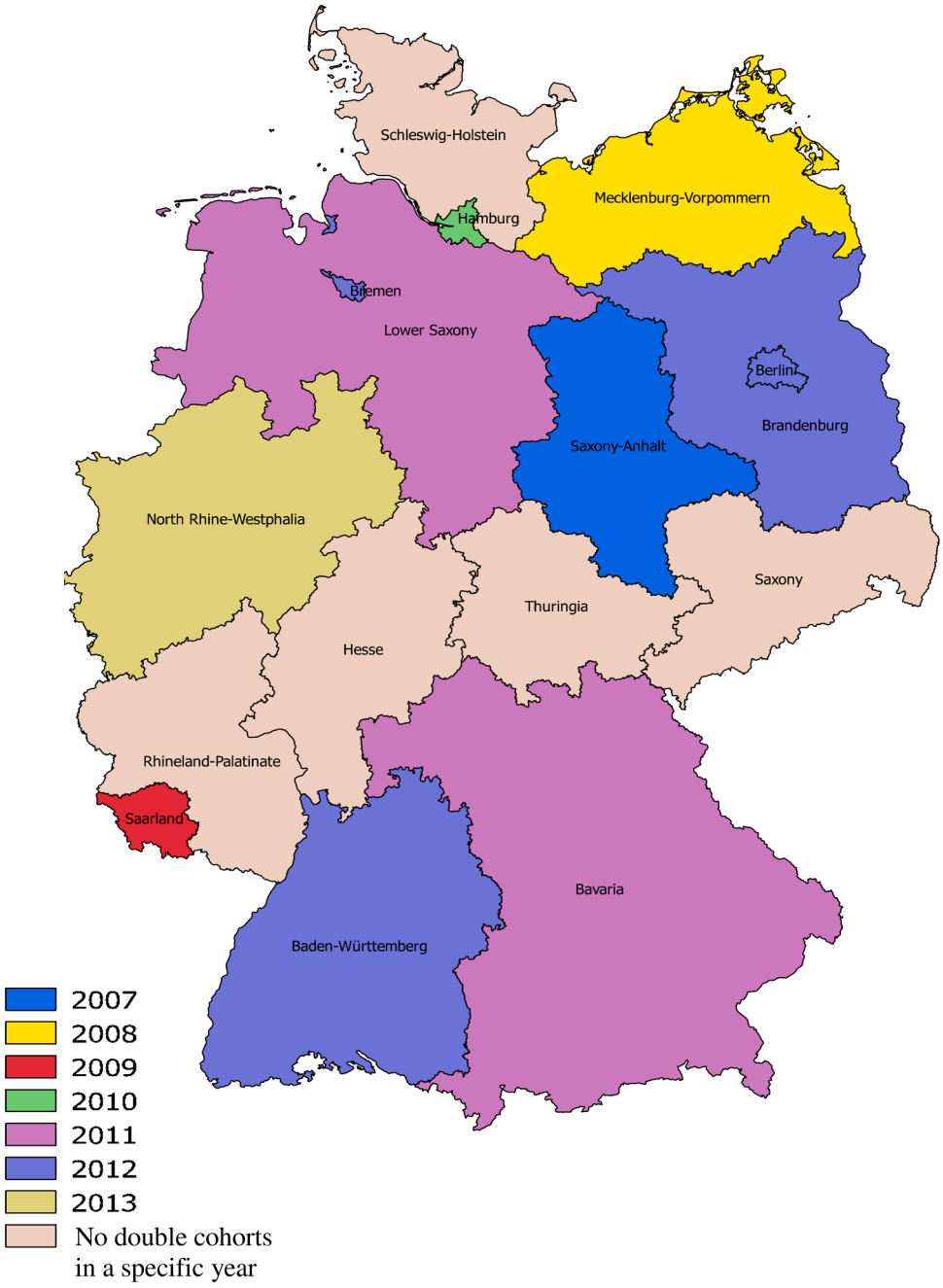
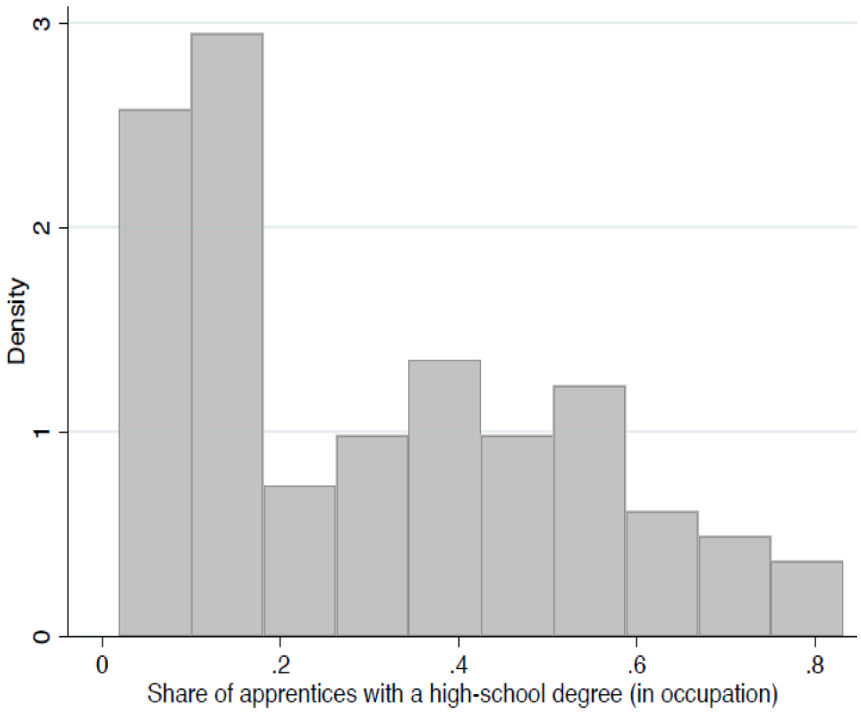


Figure A1. Map of the occurance of double cohorts due to the high school reform. Hesse is not marked, because the double cohort spread over two years (2013 and 2014).



Source: Federal Statistical Office contract data.

Figure A2. Distribution of the share of high school apprentices across occupations
Source: Vocational Education and Training statistics provided by the Federal Statistical Office and the statistical offices of the federal states.

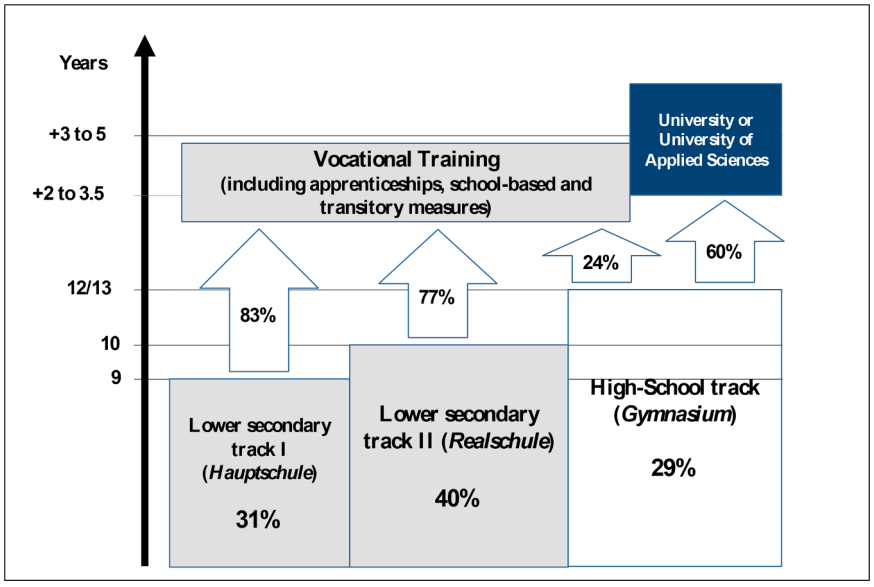


Figure A3. The German school system
Notes: The Figure depicts the main pathways and is not meant to deliver a complete picture of the German education system. Sources: Beicht and Ulrich (2008); Destatis (2011)

Table A1
Share of apprentices with residence in the same state as their workplace

Residence of apprentice (state)																
Work-place	SL	HH	MV	NI	HB	NW	HH	RP	SL	BW	BY	BE	BB	ST	TH	SN
Year prior to reform																
HH	0.20	0.60	0.02	0.14	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00
MV	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00
NI	0.00	0.00	0.00	0.94	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
HB	0.00	0.00	0.00	0.33	0.65	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NW	0.00	0.00	0.00	0.01	0.00	0.97	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BW	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.94	0.02	0.00	0.00	0.00	0.00	0.00
BY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.97	0.00	0.00	0.00	0.00	0.00
BE	0.00	0.00	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.79	0.15	0.00	0.00	0.00
BB	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.85	0.01	0.00	0.01
ST	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.94	0.01	0.02
Year of the reform																
HH	0.20	0.64	0.01	0.12	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MV	0.01	0.00	0.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.01	0.00	0.01
NI	0.00	0.00	0.00	0.95	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HB	0.00	0.00	0.00	0.32	0.66	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NW	0.00	0.00	0.00	0.01	0.00	0.97	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BW	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.93	0.02	0.00	0.00	0.00	0.00	0.00
BY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.96	0.00	0.00	0.00	0.00	0.00
BE	0.00	0.00	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.80	0.14	0.00	0.00	0.01
BB	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.83	0.01	0.00	0.02
ST	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.94	0.01	0.02

Notes: The first column indicates the location of the apprentice's workplace. Numbers indicate the share of apprentices residing in the same state as their workplace. SH=Schleswig-Holstein, HH=Hamburg, NI=Lower Saxony, HB=Bremen, NW=North Rhine-Westphalia, HE=Hesse, RP=Rhineland-Palatinate, BW=Baden-Württemberg, BY=Bavaria, SL=Saarland, BE=Berlin, BB=Brandenburg, MV=Mecklenburg-Vorpommern, SN=Saxony, ST=Saxony-Anhalt, TH=Thuringia. Source: IEB employer–employee linked data.

Table A2
Effects of the high school reform on apprenticeship contracts by within-occupation share of apprentices with a high school degree

	West Germany			East Germany		
	$\frac{a_{o,HS}}{a_{o,ALL}} < 0.25$	$0.25 < \frac{a_{o,HS}}{a_{o,ALL}} < 0.5$	$\frac{a_{o,HS}}{a_{o,ALL}} > 0.5$	$\frac{a_{o,HS}}{a_{o,ALL}} < 0.25$	$0.25 < \frac{a_{o,HS}}{a_{o,ALL}} < 0.5$	$\frac{a_{o,HS}}{a_{o,ALL}} > 0.5$
High school reform	0.080***	0.062***	0.036	0.162***	0.070**	0.047
	(0.015)	(0.017)	(0.020)	(0.059)	(0.026)	(0.029)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Occupational trends	Yes	Yes	Yes	Yes	Yes	Yes
State-level trends	Yes	Yes	Yes	Yes	Yes	Yes
State and occupation FE	Yes	Yes	Yes	Yes	Yes	Yes
Constant	3.883***	4.819***	5.007***	3.502***	4.247***	4.202***
	(0.022)	(0.025)	(0.018)	(0.057)	(0.038)	(0.034)
Observations	8092	5960	4049	3274	2960	1956
R^2	0.453	0.404	0.340	0.358	0.554	0.458

Notes: Dependent variable: ln (number of new apprenticeship contracts with a high school degree at occupation level). $\frac{a_{o,HS}}{a_{o,ALL}}$ denotes the share of apprentices with a high school degree in training occupation *o*. Clustered standard errors are in parentheses. *** Significant at the 1% level; ** significant at the 5% level; * significant at the 10% level. Weighted regressions, using number of apprentices per occupation and state as weights. Source: Vocational Education and Training statistics provided by the Federal Statistical Office and the statistical offices of the federal states.

Table A3
Effects of the high school reform on apprenticeship wages by within-occupation share of apprentices with a high school degree

	West Germany			East Germany		
	$\frac{a_{o,HS}}{a_{o,ALL}} < 0.25$	$0.25 < \frac{a_{o,HS}}{a_{o,ALL}} < 0.5$	$\frac{a_{o,HS}}{a_{o,ALL}} > 0.5$	$\frac{a_{o,HS}}{a_{o,ALL}} < 0.25$	$0.25 < \frac{a_{o,HS}}{a_{o,ALL}} < 0.5$	$\frac{a_{o,HS}}{a_{o,ALL}} > 0.5$
High school reform	0.002	0.013***	0.006	0.001	-0.003	0.016
	(0.012)	(0.003)	(0.004)	(0.021)	(0.011)	(0.0228)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Occupational trends	Yes	Yes	Yes	Yes	Yes	Yes
State-level trends	Yes	Yes	Yes	Yes	Yes	Yes
State and occupation FE	Yes	Yes	Yes	Yes	Yes	Yes
Constant	3.049***	3.014***	3.068***	2.723***	2.711***	2.914***
	(0.006)	(0.012)	(0.003)	(0.008)	(0.009)	(0.019)
Observations	2151	2141	1379	1181	885	519
R^2	0.613	0.666	0.814	0.667	0.751	0.762

Notes: Dependent variable: ln (average wage of newly hired apprentices with a high school degree at occupation level). $\frac{a_{o,HS}}{a_{o,ALL}}$ denotes the within-occupation share of apprentices with a high school degree. Clustered standard errors are in parentheses. *** Significant at the 1% level; ** significant at the 5% level; * significant at the 10% level. Weighted regressions, using number of apprentices per occupation and state as weights. Source: IEB employer–employee linked data.

Table A4
Elasticity of apprenticeship contracts with respect to lower secondary school (LS) graduates: Panel fixed-effects regression

	Model 1	Model 2	West Germany	East Germany
ln(graduates LS)	0.378***	0.378***	0.358***	0.263
	(0.045)	(0.042)	(0.113)	(0.162)
Year dummies	Yes	Yes	Yes	Yes
Occupational trends	No	Yes	Yes	Yes
State-level trends	No	Yes	Yes	Yes
State and occupation FE	Yes	Yes	Yes	Yes
Constant	1.069***	1.020***	1.389	1.863
	(0.446)	(0.423)	(1.61)	(1.573)
Observations	30321	30321	20619	9702
R^2	0.148	0.309	0.355	0.386

Notes: Dependent variable: ln(number of new apprenticeship contracts at occupation level) lower secondary school graduates. Robust standard errors are in parentheses. *** Significant at the 1% level; ** significant at the 5% level; * significant at the 10% level. Source: Vocational Education and Training statistics provided by the Federal Statistical Office and the statistical offices of the federal states.

Table A5
Elasticity of apprentice wages with respect to lower secondary school graduates: Panel fixed-effects regression

	Full sample	West Germany				East Germany			
		All	500+	50-499	<50	All	500+	50-499	<50
ln (number of lower secondary school graduates)	-0.045**	0.046	-0.025	0.028**	0.052	-0.040*	-0.065*	-0.068	-0.028*
	(0.014)	(0.041)	(0.026)	(0.011)	(0.047)	(0.014)	(0.024)	(0.027)	(0.010)
ln (number of employees)									
	0.002	0.002	0.027*	0.046***	-0.002	0.008*	-0.001	0.034**	0.004
	(0.001)	(0.001)	(0.010)	(0.002)	(0.001)	(0.002)	(0.023)	(0.008)	(0.004)
Median skilled worker wage	0.001***	0.000***	0.001***	0.004***	0.000***	0.001***	0.001*	0.002***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Average age of apprentice	0.004***	0.004***	0.003	0.005***	0.004***	0.002*	0.001	0.002	0.002
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.003)	(0.002)	(0.001)
Constant	3.151***	2.165**	3.073***	2.049***	2.069**	2.794***	3.522***	3.070***	2.628***
	(0.162)	(0.458)	(0.318)	(0.127)	(0.522)	(0.132)	(0.324)	(0.285)	(0.081)
Observations	1570276	1364539	27498	280311	1056730	205737	3809	52241	149687
R^2	0.239	0.228	0.452	0.262	0.215	0.323	0.481	0.378	0.293

Notes: Dependent variable: ln (average wage of newly hired apprentice with a lower secondary school degree). Clustered standard errors are in parentheses. *** Significant at the 0.1% level; ** significant at the 1% level; * significant at the 5% level. *Sources:* IEB, IAB-BHP, KMK.

Table A6
Effects of the high school reform on the number of apprenticeship contracts

	Full sample	West Germany	East Germany
Panel A: High school apprentices			
High school reform	0.089***	0.091***	0.056***
	(0.003)	(0.004)	(0.012)
Observations	349361	301633	47728
R^2	0.046	0.052	0.032
Panel B: Non-high school apprentices			
High school reform	0.008***	0.004**	0.011**
	(0.002)	(0.002)	(0.005)
Observations	1573407	1367050	206357
R^2	0.031	0.029	0.043

Notes: Dependent variable: ln (number of new apprenticeship contracts at firm level). Clustered standard errors are in parentheses. *** Significant at the 1% level; ** significant at the 5% level. Control variables: log number of employees, median skilled worker wage in the firm; firm fixed effects, year indicator variables, and the log number of school leavers. Sources: IEB, IAB-BHP.

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