



# Employment prospects and firm-based training — Evidence from opening the Swiss-German border<sup>☆</sup>

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## ABSTRACT

We study how improved wage opportunities for skilled workers affect firm-based training, using the 2002 opening of the Swiss labor market to German commuters as a natural experiment. The reform triggered a large outflow of skilled workers from German border regions, prompting firms to expand apprenticeship training. Using a Difference-in-Differences approach, we find a significant increase in the number of apprenticeships in affected firms in Germany despite unchanged apprentice wages. This pattern is consistent with an outward shift in apprentice supply: higher wages for skilled workers across the border made apprenticeships more attractive to young people. Our findings suggest that improvements in skilled workers' wage prospects, rather than adjusting apprentice pay, may help to address training gaps and alleviate skill shortages.

## 1. Introduction

This study answers the question of how changes in skilled workers' wage opportunities after border opening affect local adjustments of training in firms. We exploit the free movement of labor reform implemented in 2002, which allowed for sudden access by German workers to the Swiss labor market. Motivated by substantially higher wages in Switzerland, German workers commuted in large numbers from the German border regions to Switzerland after the reform. This resulted in a sizable, exogenous outflow of workers from the German side of the border.

While previous studies have examined the effect of such immigration shocks on the employment and wages of workers in the receiving (e.g., Card, 2001, 1990; Borjas, 2003; Ottaviano and Peri, 2012;

Dustmann and Glitz, 2015; Dustmann et al., 2013, 2017; Beerli et al., 2021; An et al., 2024; Glitz, 2012; Dustmann et al., 2005; Peri and Yassenov, 2019; Kuosmanen and Meriläinen, 2025) or sending (Dicarlo, 2022; Hafner and Hedtrich, 2024; Bütikofer et al., 2024) country, we examine for the first time how firm-based training adjusts to this shock in the sending country using the German apprenticeship system as an example. In Germany, apprenticeships have historically been an instrument for firms to meet their skill demands. However, as in many other countries and training systems, the German apprenticeship system has come under pressure in the past two decades because of a substantial decrease in the supply of young adolescents interested in apprenticeships (cf. Dummert et al., 2019; Muehlemann et al., 2020; BIBB, 2024). In light of this development, it is important to analyze how

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training markets function and how training decisions of individuals and firms are affected by changes in skilled workers' wage opportunities.

To clarify the underlying mechanisms and develop hypotheses regarding the expected changes in apprenticeship numbers and wages following the opening of the borders, we use a simplified labor market model in which firms rely on just two input factors – skilled workers who have completed an apprenticeship<sup>1</sup> and apprentices – both of which are considered gross substitutes (see Borjas, 2013, 2003). As apprentices can already perform the tasks of skilled workers during their training period – even if only partially –, firms can substitute apprentices for skilled workers.

After the border opens, skilled workers are attracted by higher wages across the border and are more likely to seek employment opportunities abroad. Firms across the border recruit the most productive of these cross-border workers. As theory predicts, this leads to an outflow of high-ability workers, thereby reducing the average productivity of skilled labor in the home country (Roy, 1951; Borjas, 1987). The outflow of workers makes apprentices an attractive substitute for these skilled workers. Another mechanism increasing apprentice demand operates through higher regional consumption, as cross-border workers bring back higher wages that raise local spending. This increased product demand can also lead to increased demand for apprentices because of the total increase in labor demand. Taken together, firms increase their demand for apprentices to compensate for the lower availability of skilled workers and increased hiring costs of skilled workers. In addition, they increase apprentice demand to secure their future skill supply, which many firms in Germany do via investments in apprenticeship training (Mohrenweiser and Backes-Gellner, 2010).

For our empirical analysis, we apply a difference-in-differences (DiD) framework leveraging the variation in treatment intensity by the distance of the firm to the Swiss border. We use rich administrative data sets from Germany and from Switzerland, from both sides of the border. With these data we are able to use the geographic location of firms and calculate actual travel times to the border – not distances as the crow flies –, which is important due to exogenous variations in travel time determined by the access to border crossings (for example, due to the limited number of bridges across the border river Rhine). Using travel time is important for our identification strategy because the data show that the opening of borders for German workers almost only affected commuting behavior in municipalities with very short travel distances to Switzerland (less than 30 min). We compare changes in firm-based training between firms in treated regions (within 30 min to the border) and firms in matched control regions outside the border area elsewhere in Germany. This enables us to identify causal effects of opening the border on firms' training behavior. Furthermore, to assess effects on the apprenticeship market as a whole, that is to account also for firm entries and exits, we complement our firm-level analyses by a region-level analysis.

In line with our theoretical considerations, we find the number of apprenticeships increased in the treated firms and regions while apprentice wages did not increase. Apprenticeship training in firms increases, both at the extensive margins (firms providing training or not) and the intensive margins (number of apprentices in training firms). We argue that this can be explained by demand-side and supply-side mechanisms: 1. On the demand side, when skilled workers flow out of the region due to opening the borders, apprentices can serve as gross substitutes for skilled workers, so demand for apprentices increases. In addition, we find that skilled worker employment increases as well, which can be explained by increased product demand from cross-border workers that earn higher wages in Switzerland and a by a decline in average worker productivity as the most productive workers are more likely to find work abroad and leave. 2. On the supply side, opening the

border improves the earning opportunities of apprenticeship graduates due to substantially higher wages across the border in Switzerland, enhancing the attractiveness of apprenticeship training.

This study contributes to the literature in two ways. First, it complements the literature on the effects of negative labor supply shocks in industrialized countries (Dicarlo, 2022; Hafner and Hedtrich, 2024; Bütikofer et al., 2024). Previous studies have focused on the effects of worker inflows on native employment and wages in the receiving country or the effects of worker outflows on employment and wages in the sending country. While some studies also analyzed effects on education attainment in the receiving (Bächli and Tsankova, 2025; Hunt, 2017; McHenry, 2015; Oswald-Egg and Siegenthaler, 2023; Llull, 2018; Aepli and Kuhn, 2021) or the sending country (e.g., Docquier and Rapoport, 2012), none have studied the effects of worker outflows on firm-based training in the sending country. We close this gap by investigating not only the effect on firm-based training but also on training wages, and ultimately expounding on the effects of an outflow of workers on regional labor market prospects and human capital formation in the sending country after the opening of borders.

We use a reform regulating cross-border work between Switzerland and Germany as a natural experiment. Previous literature by Oswald-Egg and Siegenthaler (2023) and Aepli and Kuhn (2021) has only looked at effects on the training market in the receiving country (Switzerland).<sup>2</sup> While classical economic theory would suggest symmetric or mirroring effects in both the sending and receiving countries (Germany and Switzerland), substantial institutional differences in the apprenticeship systems and labor market regulations between the two countries (cf., Beicht et al., 2004; Schweri et al., 2003; Dionisius et al., 2010; Muehlemann et al., 2010; Muehlemann and Wolter, 2014) may fundamentally alter this expected symmetry. This study contributes by analyzing the reform effects on the German system in which apprenticeships to a greater extent serve as an investment into the future skill supply of firms. Furthermore, we argue that, in the German case, apprentices can expect much larger wage opportunities after the border opening which makes apprenticeships more attractive.

Second, by concentrating on the effects on apprenticeship training, our study adds to the broader literature on the effects of labor market shocks on the market for apprenticeships (Muehlemann et al., 2022; Lüthi and Wolter, 2020; Dorner et al., 2024; Aepli and Kuhn, 2021; Oswald-Egg and Siegenthaler, 2023; Wittek and Muehlemann, 2021). By identifying the effect of an emigration-driven negative labor supply shock on workers and firms, we can draw important conclusions regarding the functioning of apprenticeship training markets. On the demand side, firms react to the negative supply shock and the subsequent change in relative labor costs by substituting apprentices for skilled workers. This suggests that firms are sensitive to both the costs of skilled workers and apprenticeships. On the supply side, the attractiveness of apprenticeship training seemingly depends more on wage opportunities of apprenticeship graduates, that is, on attractive skilled worker wages than on apprentice wages. In our empirical example, firms can hire more apprentices although apprentice wages did not change. These findings are consistent with a supply-side response, whereby higher post-training earning opportunities abroad after the border opening increase the propensity to enter apprenticeship training.

While our results concern the market for apprenticeship training in Germany, they expand to other countries with apprenticeship training systems and to other countries and types of occupations in which training takes place while working in companies or public institutions

<sup>1</sup> In the following, we refer to apprenticeship graduates as skilled workers not including university graduates.

<sup>2</sup> In previous studies on the effects of the AFMP on the Swiss apprenticeship market (Aepli and Kuhn, 2021) find that apprentice numbers declined by 2% after the reform and Oswald-Egg and Siegenthaler (2023) find insignificant effects of the reform on apprenticeship in Switzerland, the receiving country, but they do not provide any evidence on the sending country.

such as training of PhDs, auditors, lawyers, or teachers. Our results imply that firms are both willing and able to use the training of young labor market entrants as a means to meet their skill demands if the cost–benefit ratio of training is advantageous. However, the key to mobilizing the young generation to invest in training is to increase the long-term benefits of training, that is, the wages received by graduates of apprenticeships, PhD graduates, fully trained auditors, or lawyers receive (and the societal reputation accompanying it).

## 2. The agreement on the free movement of persons and its importance for the German apprenticeship market

In the following, we investigate how a negative supply shock of workers with a completed apprenticeship affects the number of apprentices and their wages. We study this using the example of the introduction of the Agreement on the Free Movement of Persons (AFMP) between Switzerland and the EU, which in the early 2000s substantially facilitated cross-border commuting for so-called cross-border workers (CBW) residing in Germany and working in Switzerland. In two steps, the AFMP removed restrictions for CBWs, resulting in large outflows of German workers seeking employment in Switzerland, mainly from regions near the Swiss–German border, where commuting costs are low.

Before the border opening (i.e., before 2002), becoming a CBW was possible but highly restricted and subject to specified conditions that made access to the Swiss labor market costly. The most important restriction was that companies had to comply with the so-called *priority requirements*. These priority requirements obliged Swiss firms to prove that no suitable Swiss candidate was available for a particular job before hiring a foreign worker. A second important restriction was that cantonal authorities were required to inspect the salaries and working conditions of CBWs before issuing work permits. Moreover, the AFMP defined a number of German districts close to the border in which CBWs were required to reside (AFMP regions henceforth, see Fig. 2), and to commute daily to their municipality of residence. The AFMP regions comprised the city of Freiburg, the city of Kempten (Allgäu), the districts Breisgau – Hochschwarzwald, Lörrach, Waldshut-Tiengen, Schwarzwald – Baar-Kreis, Tuttlingen, Konstanz, Sigmaringen, Biberach, Ravensburg, Bodenseekreis, Lindau (Bodensee), and Oberallgäu.<sup>3</sup> These restrictions entailed substantial administrative costs for both CBWs and Swiss firms seeking to hire German CBWs. The AFMP was signed in 1999, came into force in 2002, and gradually lifted restrictions in two phases. Beerli et al. (2021) define the first phase of the AFMP as (1) the **Transition Phase** between 1999 and 2003. It starts with the announcement of the AFMP and covers anticipatory effects as well as first relaxation effects. Anticipatory effects occurred between 1999 and 2001, that is before the reform came into force. First relaxation effects occurred between 2002 and 2003 when the requirement of a mandatory daily commute was substituted with a weekly commute. Beerli et al. (2021) define the second phase from 2004 onwards as (2) the **Free Movement Phase**, which eliminated both the priority requirement granted to Swiss workers and the cantonal authorities' inspection of salaries and working conditions. This significantly reduced Swiss firms' costs of recruiting CBWs.

After changing the legal framework, the AFMP induced a large outflow of workers from Germany to Switzerland. This outflow concerned all skill levels, meaning workers with vocational degrees (e.g., apprenticeships), academic degrees as well as workers without any formal training. This study is the first to analyze the impact of the total outflow on the apprenticeship market in Germany. The reason for this focus is not that the outflow was biggest for workers with a vocational degree,

but that the labor market for workers with completed apprenticeships or similar vocational degrees is by far the largest in Germany, capturing about three fourth of total employment.

Apprenticeships combine on-the-job training in a firm with occupation-specific but also general course work at a vocational school of the municipality. The hours spent on each are laid out in the apprenticeship contract. Upon program completion, apprenticeships lead up to a state-centralized final exam and a state-certified vocational degree. German apprentices typically are adolescents that enter training right after leaving school when they are between 16 and 19 years old, depending on their high school track. If not opting for an apprenticeship, adolescents below the age of 18 must continue general school education or enter a school-based vocational track<sup>4</sup>; adult school leavers may also enter university if they have graduated and received an Abitur (a university entrance certificate) or enter the labor market directly as an untrained worker. Although apprentice numbers have been declining lately, more than 50% of adolescents still start an apprenticeship at some point in their labor market biography (BIBB, 2024).

After the reform was announced, the Swiss Cross Border Commute Statistics (CBCS) shows that the number of CBWs also increased dramatically in the typical occupational fields of apprenticeship graduates (see Fig. A.1). The main reason for these outflows lies in the relatively high financial benefits of working as a CBW owing to higher gross wages in Switzerland. The net returns are substantially higher despite the fact that the German side of the border is comparably prosperous and providing good employment opportunities. The German border region is characterized by high GDP per capita, low unemployment rates, and high average income (cf. BMI, 2020). Nonetheless, wage data show that becoming a CBW in Switzerland is attractive, especially for skilled workers. Average wages in Switzerland are roughly 36% higher than those in Germany (OECD, 2021). In some typical apprenticeship occupations, the wage differential is larger. For example, between 1998 and 2002, for technicians and associate professionals, wages were on average about 70% higher on the Swiss side of the border (see Table B.1).<sup>5</sup> Additionally, while earning Swiss wages, CBWs in Germany benefit from lower living costs. For example, per OECD (2023), in 2021, the cost of living in Germany is 39% lower than that in Switzerland. These high financial incentives to leave Switzerland as a CBW are well-known and frequently taken advantage of.<sup>6</sup>

Furthermore, searching for a job in Switzerland is comparatively easy because of the high comparability between the German and Swiss apprenticeship system. German workers also have access to information on cross-border work and support for their job search in Switzerland via several channels, such as information sessions and job boards in vocational schools, job fairs, a plethora of private agencies, and even public programs.<sup>7</sup>

Hence, the AFMP provided highly profitable opportunities in the Swiss labor market for workers who completed their apprenticeship

<sup>4</sup> School-based vocational tracks mostly train different occupations than apprenticeships. Most common examples are health and care occupations.

<sup>5</sup> We compare Swiss and German wages using the Swiss Labour Force Survey (SFLS), a survey of 1% of Swiss households, and the German Sample of Integrated Labour Market Biographies (SIAB), a 2% sample of employees covered by social security since 1975. We calculate average wages in 1999–2002 for workers aged 18–64, excluding apprentices and self-employed by ISCO-08 first-digit occupational field, Swiss wages converted from Swiss Francs to Euro using the 2002 average exchange rate.

<sup>6</sup> As represented by a recent news article in Vuillemin (2023) titled “Since I work in Switzerland, I wallow in luxury”.

<sup>7</sup> An example of this is EURES (European Employment Services), a cooperation network of public employment services in the European Union (EU) and the countries in the European Free Trade Association (EFTA) aiming at facilitating the mobility of workers within these countries. EURES is active in the border region, especially in the regions of Oberrhein and Bodensee.

<sup>3</sup> These districts were defined by the “Abkommen zwischen dem Schweizerischen Bundesrat und der Regierung der Bundesrepublik Deutschland über den Grenzübertritt von Personen im kleinen Grenzverkehr (1970) AS 1970 1020 (CH)”.

in Germany. We argue that improved earning opportunities are an important factor influencing young adolescents' decision to enter apprenticeship training. Previous studies (e.g., Bajka et al., 2025; Dräger and Wicht, 2023; Eberhard et al., 2022) show that post-training wages are a key determinant both of the decision for or against apprenticeship training and of the choice of specific occupations within apprenticeship training.

### 3. Theoretical considerations

To develop hypotheses on the effects of the AFMP on apprentice numbers and wages, we consider a simplified version of the labor market in which firms produce output with just two input factors (skilled workers and apprentices). For both types of labor, wages are mostly set by collective bargaining agreements (Schnabel, 2025; Oswald-Egg and Siegenthaler, 2023; Muehleman et al., 2022), which can be raised by firms but not undercut, thereby creating downward wage rigidity. Furthermore, we assume apprentices are gross substitutes for skilled workers. Firm-level surveys on costs and benefits (e.g., Wenzelmann and Schönfeld, 2022) show that apprentices perform considerable amounts of skilled work during their training time in the firm. For example, in the first year of a three-year training, apprentices spend overall 66% of their working days with productive tasks and almost half of this time (24% of their working days) with performing tasks at the skilled worker level. By the third year, the time spent on tasks on skilled worker level even amounts to 50% of the total working days. Hence, although apprentices have a generally lower productivity than skilled workers, they are able to perform skilled worker tasks. We, therefore, assume that they can be considered as gross substitutes but would be needed in larger numbers.

In the equilibrium of this simplified model, the firm will choose a mix of skilled workers and apprentices that minimizes costs and maximizes benefits. When hiring an apprentice instead of a skilled worker, the firm saves on wage costs, which are substantially lower for apprentices even given lower productivity. It also saves on hiring costs for skilled workers, which may be high in the presence of a shortage of skilled workers (cf. Linckh et al., 2024). In turn, the firm has to bear the costs of training. In Germany, in many cases these costs of employing an apprentice may exceed their productive value, and firms may only be able to recoup the net costs when retaining the apprentice after the training period (Muehleman et al., 2010) and setting wages for retained apprentices below the market rate (Acemoglu and Pischke, 1999a,b). According to Mohrenweiser and Backes-Gellner (2010), many firms in Germany are such investing firms, meaning that they use apprenticeship training as a strategic means to invest in their future skilled workforce.

Opening the border for cross-border commute causes a shock to the equilibrium. A proportion of skilled workers flows out of the bordering labor market to work in Switzerland for a much higher wage (see Table B.1). This has several dynamic implications to the simplified model: 1. The supply of skilled workers for firms in border regions decreases. This increases labor market tightness and puts upward pressure on wages. This tightness increases hiring costs for skilled workers, making it relatively cheaper for firms to substitute apprentices for skilled workers. 2. The higher wage level of CBWs, meaning workers living in one country (Germany) but commuting across the border to work in another country (Switzerland) for much higher wages, increases consumption and product demand in their home country. This may increase labor demand and further increase labor market tightness. 3. Theory predicts that emigrants, here workers who commute to work abroad, are positively selected on productivity (Roy, 1951; Borjas, 1987). Therefore, we expect that the average productivity level of the remaining skilled workers is potentially lower than before. This indirectly raises labor demand when more skilled workers are needed to achieve previous production levels. At the same time, the decrease in skilled worker productivity decreases the productivity gap

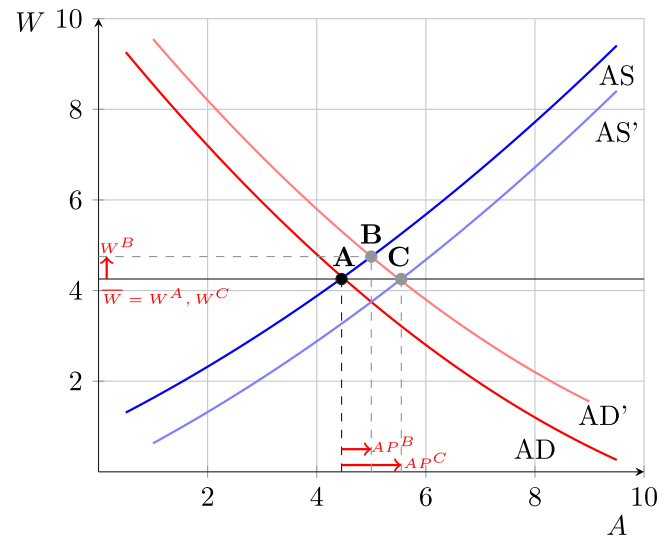


Fig. 1. Apprentice supply and demand with downward-rigid wages.

between apprentices and skilled workers. Hence, apprentices become more attractive as substitutes for skilled workers.

Considering these dynamics, classic economic theory predicts that firms will choose to substitute apprentices for skilled workers (cf., Borjas, 2003, 2013). In a simple diagram of apprentice demand and supply (Fig. 1), apprentice demand (AD) shifts outward. When apprentice supply (AS) does not shift, apprentice wages increase and the number of apprentices increases to  $AP^B$  (point B in Fig. 1). An increase in the number of apprentices at rigid wage floor ( $\bar{w}$ ) is only possible if the apprentice supply shifts outward accordingly (point C in Fig. 1). In this case, the number of apprentices increases even more to  $AP^C$ . Hence, we expect that apprentice numbers increase in response to the AFMP (H1).

The effect on apprentice wages depends on the shift in apprentice supply. In case of the border opening, it is plausible that apprentice supply increases. Cross-border work increases job opportunities and wage expectations after the apprenticeship across the border where wage levels on average are substantially higher (see Table B.1). Therefore, we expect that apprentice wages do not increase as apprentice supply increases (H2).

### 4. Empirical strategy

In the following analyses, we test these hypotheses using a DiD approach for causal identification. For this, we compare firms located at the border before and during the two reform phases with firms in unaffected control regions. To do this, we first select suitable control regions using Mahalanobis nearest neighbor matching to resemble the AFMP regions' economic and labor market structure as close as possible while located far enough from the border where commuting to Switzerland is infeasible (see Section 4.1, and gray areas in Fig. 2).

Second, within the AFMP regions, we define the direct border regions (BR henceforth) that were most affected by the AFMP. For this, we exploit the fact that access to the Swiss labor market affected German firms before the reform and afterward in different ways depending on their geographic location owing to bridges, mountains, or road availability, because travel distances determine whether commuting is actually feasible for their workers in a sufficiently short time. This enables us to divide the AFMP region into two regions of low and high exposure of firms to the reform. In Fig. 2, highly exposed regions are located directly at the border (BR, dark green areas) in vicinity of Swiss cities (orange areas) and other AFMP regions are located farther away (light green areas).

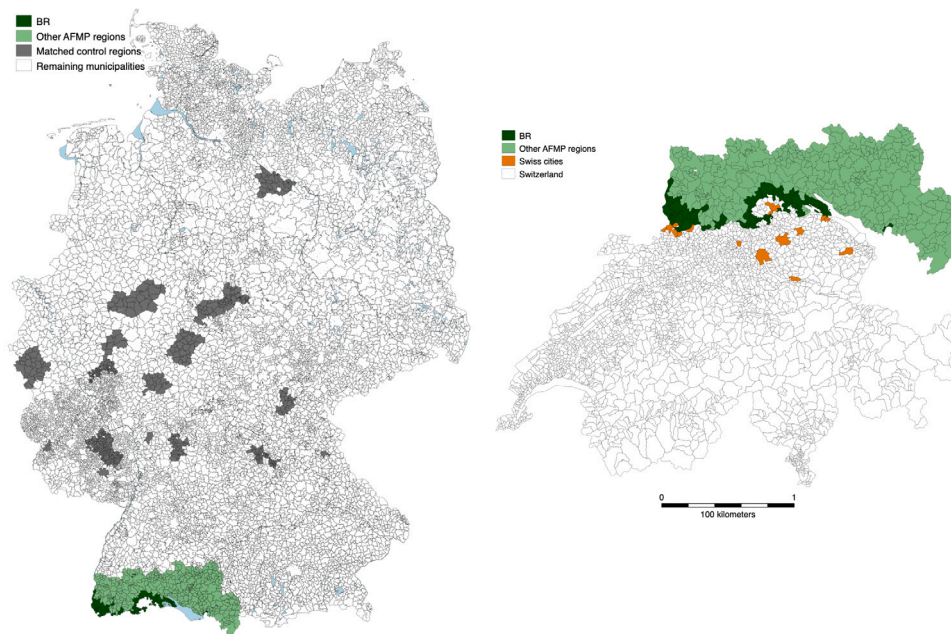


Fig. 2. Treatment and control regions.

Note: Map of Germany (left), AFMP region and Switzerland (right), BR regions (dark green), other AFMP regions (light green), matched control regions (gray), nearest Swiss cities from BR (orange), remaining municipalities (white) are excluded from the analysis. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

In the following, 1. we explain our matching approach for control regions located outside the AFMP regions, 2. define the direct border region (BR), and 3. outline the empirical specification.

#### 4.1. Matched control regions

To evaluate the reform effects in the regions for which the AFMP allowed cross-border commute before 2007 (AFMP regions), we must compare their development with those in comparable untreated regions. For this, we do not use all available control regions but apply nearest-neighbor matching. This ensures data sparseness by limiting the number of control regions and the pre-reform comparability of treatment and control regions by selecting control regions that are as similar as possible to the AFMP region in terms of labor market characteristics.

To select good matches, we use the Establishment History Panel (BHP) of the Institute for Employment Research. As a 50% sample of the entire universe of German firms, these data are the largest available data source on German firms and can be used to describe regional labor and apprenticeship markets in detail. Using this data on the level of districts for 1998, we match nearest neighbor districts to the AFMP districts using Mahalanobis distance matching with replacement. The goal of this exercise is to find matches that 1. are located at least 3 h away from the border, such that it is unlikely that these regions were affected by the AFMP themselves and 2. have similar apprenticeship and labor market as well as population characteristics as the AFMP regions. To ensure the latter, we match on the districts' total employment levels, shares of low skilled workers (without a vocational or tertiary degree), shares of high skilled workers (with a tertiary degree), shares of employment in manufacturing, the log of mean worker wages, and proportions of right-censored wages.<sup>8</sup> We also account for

<sup>8</sup> Administrative records only document wages as long as they are subject to social security contributions. Higher-income earners are eligible for private social security. Censored wages above this social security limit were imputed in the data set.

population density, net numbers of cross-district commuters, and levels of apprenticeship employment in 1998, which we retrieve from the INKAR database.<sup>9</sup>

To ensure that the control regions are unaffected by the AFMP (e.g., by spillover effects from neighboring regions), we only consider matches located at least three hours away from the Swiss border. However, to select districts that are as similar as possible, we only consider other districts in West Germany and not in East Germany because of the persistent underlying structural differences in apprentice demand and supply between West and East Germany (cf. Riphahn and Zibrowius, 2016). For each border region district, we select as many nearest neighbors as possible outside the border region until the sum of their employment levels equals at least 1.5 times that of the respective border region districts, in line with Dustmann et al. (2017). To account for this disproportionate selection, we weight control group observations accordingly in our estimations.

In total, we match 19 control districts<sup>10</sup> comprising 555 municipalities.

Overall, the resulting matched control regions were comparable with the AFMP regions. Table B.2 shows that for 1998 (the year before the announcement of the AFMP), by considering the selected control regions instead of all German districts, we could compare districts with a higher degree of similarity, especially with regard to population density, the unemployment rate, average number of firms in a district, and the share of manufacturing employment.

<sup>9</sup> INKAR is operated by the Federal Institute for Research on Building, Urban Affairs and Spatial Development. The population density is based on employment data from the Federal Employment Agency and the land area survey of the Federal Statistical Office and the Statistical Offices of the Länder. The data on apprenticeship employment and net commuters are based on surveys conducted by the Federal Employment Agency.

<sup>10</sup> The matched control districts are Lüchow-Dannenberg, Göttingen, Soest, Aachen, Düren, Paderborn, Olpe, Altenkirchen (Westerwald), Darmstadt, Gießen, Bad Kreuznach, Miltenberg, Schwalm-Eder-Kreis, Trier, Donnersbergkreis, Weiden i.d.OPf., Kronach, Erlangen-Höchstädt, and Kaiserslautern located in the federal states of Lower Saxony, Northrhine-Westphalia, Rhineland-Palatinate, Hesse, Baden-Württemberg, and Bavaria.

#### 4.2. Definition of the border regions

For identification, we exploit the fact that the AFMP mainly affects firms located close to the border. Initially, commute restrictions were lifted only for residents of the AFMP regions, thereby clearly defining a treatment group for the reform. However, across municipalities within this AFMP regions, there are strong differences in the number of CBW residents and, therefore, in the actual local outflow of workers from the region. These differences in the AFMP regions arise because of different travel times within a region to the Swiss labor market because of the distance to the border as well as preexisting roads and bridges across the river Rhine. Before the AFMP commuting to Switzerland was not impossible. However, because it was heavily restricted before the AFMP and came at high bureaucratic costs, the numbers of CBWs were small despite low travel times to Switzerland. After the AFMP, many new employment possibilities for the entire workforce suddenly opened up across the border such that CBW numbers soared thereafter (see also Aepli and Kuhn, 2021; Oswald-Egg and Siegenthaler, 2023).

We use this fact to distinguish between AFMP regions of low and high treatment intensity, where assignment of firms to groups can be seen as exogenous, assuming that access to roads and bridges across the border was irrelevant for most workers' labor market and location decisions prior to the opening of the border. According to the Micro-census (2010), more than 70% of German workers commute for less than 30 min to their workplace. However, the travel distance, meaning the commuting time from municipalities in the AFMP regions to the next Swiss city varies between 5 and 105 min. Therefore, the AFMP provides the opportunity to commute to Switzerland within the typical 30 min only in some regions, namely the border regions (BR). In other AFMP regions, that are municipalities located farther away, workers on average would have to commute longer to Switzerland than before and longer than they typically would if they stayed in Germany. Hence, the former group can switch to Switzerland without any changes in commuting costs, whereas the latter group has higher commuting costs.

Similar to Beerli et al. (2021), we leverage this fact by using travel distance to distinguish between municipalities with high and low direct exposure to worker outflows following the AFMP. For this, we calculate travel distances in minutes by car from the center of each AFMP region municipality to the next Swiss city.<sup>11</sup> The travel distances describe the commuting times by car and not aerial distance.<sup>12</sup> In this way, we consider the actual accessibility of the Swiss labor market, which is not only determined by distance but also by transport infrastructure, such as roads and bridges.

We use the 30-minute mark to distinguish between high and low treatment intensities according to geographic location within the border region.<sup>13</sup> We find that the number of CBWs in municipalities located farther than 30 min away from the next Swiss city becomes very small (except for two outliers). This is shown in Fig. A.2, Panel A, which plots the average travel distance in minutes to the next Swiss city against the number of CBWs for each municipality in the AFMP regions in 2002 and the predicted numbers of CBWs from an estimation of a fractional polynomial of travel time (fitted line). The number of CBWs

and their municipality of residence is known from the Swiss Cross-Border Commuter Statistics (CBCS), which is a full count of CBWs in Switzerland.<sup>14</sup> The graph shows that when the AFMP came into force in 2002, CBWs were concentrated in municipalities within a travel distance of 30 min to the next Swiss city (vertical line).

Six of the eight municipalities with 1000 or more CBW residents lie within this travel radius. The outliers with travel times above 30 min but with high numbers of CBWs are the cities of Freiburg and Waldshut-Tiengen. Past the mark of 30 min, the number of CBW residents in municipalities approaches zero on average. The picture is similar, when plotting the ratio of CBWs to workers covered by social security in the municipalities. Fig. A.2, Panel B, shows that, in 2002, in some municipalities very close to the border, there were more than 1.5 CBWs per worker residing in the municipality. Past the mark of 30 min travel time, there are no municipalities with a ratio larger than 0.5 CBWs per worker (see Fig. A.2, Panel B).

The concentration of CBWs in the BR (within the travel radius of 30 min) continuously increased after the announcement of the AFMP. Using the CBCS data, which is available from 1999, we illustrate the increase in the ratio of CBW residents per worker (covered by social security) from 1999 to 2018 in Fig. 3. The share of CBWs started to pick up directly after the announcement and intensified continuously thereafter. Over this time span, the CBWs ratio almost doubled in the BR, from 0.13 CBWs per worker in 1999 to a ratio of 0.24 in 2018. In total, cross-border commute increased from 22,358 CBWs in 1999 to 47,046 CBWs in 2018 in the BR. In contrast, municipalities in other AFMP regions experienced a very moderate development in the CBWs ratio, while in the matched control regions, the ratio of CBWs working in Switzerland per worker remained almost zero throughout the years.

#### 4.3. Empirical specification

To estimate the effect of the AFMP on the number of apprentices and apprentice wages in firms, we apply a DiD framework to measure the difference in our outcomes of interest in treated firms in the AFMP regions compared to firms in the control regions before and after the reform. We distinguish between two different regions in the AFMP regions: 1. firms located in municipalities of the BR (within 30 min of travel distance to the next Swiss city), as indicated by the dummy variable *BR* and 2. firms located in other AFMP regions farther away, as indicated by the dummy variable *other AFMP*. In contrast, the control firms are located in the matched control regions outside the AFMP regions.

The average treatment effects on the treated (ATT) in years  $t$  are measured by the interaction coefficients of *BR* and *other AFMP* with the year fixed effects,  $\tau$ . We are especially interested in the coefficients  $\delta_t$ , which measures the ATT in BR firms relative to control firms. Our model takes the following form:

$$Y_{it} = \alpha + \tau_t + \zeta_i + \beta_1 BR_i + \beta_2 other\ AFMP_i + \delta_t \tau_t \times BR_i + \beta_{3t} \tau_t \times other\ AFMP_i + \epsilon_{it}, \quad (1)$$

where  $\alpha$  is constant,  $\zeta$  is the firm-fixed effect for firm  $i$ , and  $\epsilon$  is an error term. Overall, our model specification is similar to that proposed by Beerli et al. (2021). We cluster the standard errors at the level of 62 municipal associations,<sup>15</sup> which are more detailed than districts but much broader than municipalities to ensure sufficient observations in each cluster.

We conduct firm-level analyses to quantify effects on the amount of apprenticeship training carried out by firms. This analysis abstracts

<sup>11</sup> As Swiss cities we considered municipalities with either high employment levels and/or high CBWs numbers. The 17 considered Swiss cities are Baden, Rheinfelden, Muttentz, Pratteln, Allschwill, Basel, Riehen, Au, Rapperswil-Jona, Sankt Gallen, Neuhausen am Rheinfall, Schaffhausen, Frauenfeld, Kreuzlingen, Tägerwil, Winterthur, and Zürich. The distance is always measured to the city that is closest in terms of travel time by car.

<sup>12</sup> We use stata's georoute package which calculates travel time between two addresses to compute travel distances with the HERE application programming interface (API) (<https://developer.here.com>).

<sup>13</sup> To ensure that our results were not driven by the selection of the 30-minute cut-off, we conduct additional robustness test using other cut-offs and a continuous measure of distance to the next Swiss city; see Section 6.2, Figs. A.3, A.4, and Table B.7.

<sup>14</sup> CBWs are not observed in German administrative data.

<sup>15</sup> Municipal associations (in German: Gemeindeverband) are unions of at least two municipalities to jointly perform public administration tasks, while maintaining the independence of the member municipalities.

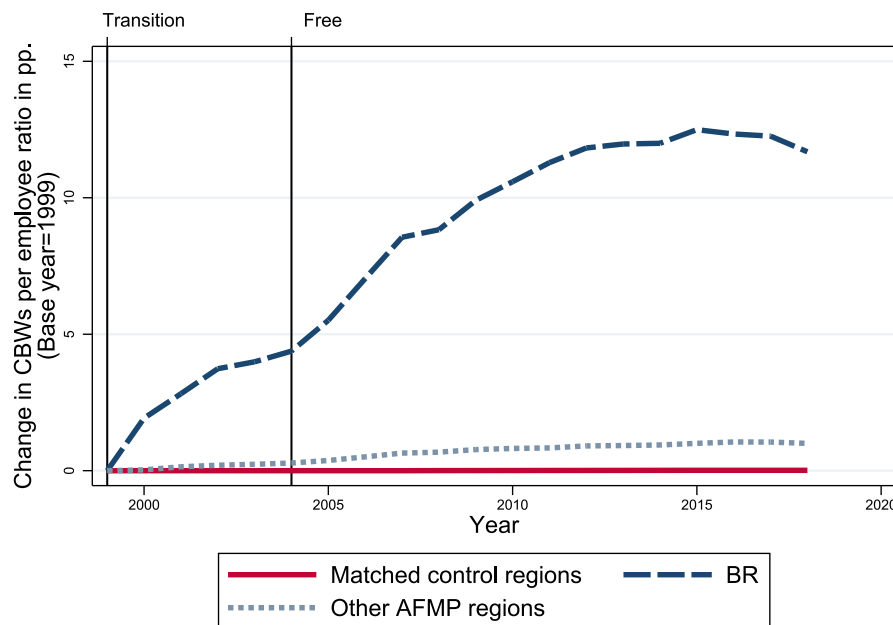


**Fig. 3.** Increase in CBWs-per-worker ratio in percentage points in BR, other AFMP, and matched control regions.  
 Note: Base level in 1999 in BR: 0.13; other AFMP regions: 0.1; matched control regions: 0 CBWs per worker.  
 Source: CBCS and Employment Statistics of the Federal Employment Agency (BA) 1999–2018.

from market dynamics such as firm entries and exits. However, to explore the importance of entries or exits for our results, we complement our firm-level analyses with region-level analyses (see Section 6.2). Furthermore, in our main results, we use weighting to account for the disproportional selection of the matched control regions (see Section 4.1). However, we do not weight by firm size in the main analysis to show the training effect in an average training firm in the relevant market, which is usually small or medium-sized (and would be underweighted by firm size weights). But in the robustness checks we also show results weighted by firm size to see whether putting weight on larger firms changes our results, which it does not (see Section 6.2).

## 5. Data and sample description

Certain data requirements must be satisfied to estimate Eq. (1). First, we need firm-level data on apprenticeship training that cover sufficient observations before the announcement of the AFMP and during the two reform phases. Second, we need data that provide detailed information on firm location and a sufficiently large sample of firms in the comparably small BR. The BHP, which we used to match the control regions, would be a good candidate, as it represents the largest available firm-level dataset for Germany, holding information on 50% of all establishments. However, it does not include information on apprentice wages. Therefore, for our analyses, we use a custom sample of the Employee History (Beschäftigtenhistorik - BeH) of the IAB<sup>16</sup> for 1993 to 2018.

The BeH contains the annual employment and end-of-employment notifications of all employees covered by social security (since 1975) and employees in marginal part-time employment (since 1999) submitted by employers to responsible social security agencies. This includes the vast majority of workers and apprentices in Germany.<sup>17</sup> The data

can be combined to construct labor market biographies of workers as well as employment structures and turnover at the establishment level.

These data offer several advantages to our analysis. 1. Firms can be located at the municipality level, making it possible to assess their distance from the next Swiss city and thereby identify them as BR firms. 2. The BeH is the largest available database on employment with this level of regional detail. We were able to use a 20% random sample of firms that are located in the AFMP regions or the control regions in 1998. This ensures a sufficiently high representation of apprentices and apprentice wages in the BR over a long period. 3. The data provide reliable information on the number of employees and apprentices as well as their gross daily wages. This enables us to analyze both employment and wage effects for apprentices.

We draw a 20% sample of the entire universe of establishments that appeared in the registries of the Federal Employment Agency (BA) on June 30, 1998, and are located either in the BR, in other AFMP regions or in a matched control region. For these firms, we use the employee biographies in the BeH to construct a panel containing the number of employed workers and apprentices and their wages for each year between 1993 and 2018 on September 30. We only consider firms that did not move into or out of their municipality during the entire observation period.<sup>18</sup> Furthermore, we focus our analysis on private-sector firms and exclude the public administration sector because this labor market has its own specific features that make it not comparable to the private sector.<sup>19</sup> In general, we deflate wages and

<sup>17</sup> Self-employed persons, civil servants, and unemployed students are not included in the data because they are exempt from social security contributions.

<sup>18</sup> We do not restrict the analysis to a balanced sample of establishments. This means that we include establishments that close down during the observation period. All included firms are observed at least one year before the reform in 1998. We show the robustness of results when using a balanced sample in Section 6.2, see Table B.5, Columns 3 and 4.

<sup>19</sup> The adjustment of apprenticeship demand in the public administration sector is likely to show a lower correlation with changes in the economic

<sup>16</sup> The data are first registered by the health insurance companies, collected and processed by the German Federal Employment Agency (BA), and then integrated into the Employee History File by the IAB (Vom Berge et al., 2021).

**Table 1**  
Worker and apprentice characteristics in 1998 by firm location.  
Source: BeH 1998.

|                                      | BR     |        | Other AFMP<br>regions |        | Matched<br>control regions |         |
|--------------------------------------|--------|--------|-----------------------|--------|----------------------------|---------|
| <i>Apprentices</i>                   |        |        |                       |        |                            |         |
| Share Abitur                         | 0.12   | (0.33) | 0.14                  | (0.35) | 0.17                       | (0.37)  |
| Share foreign                        | 0.10   | (0.30) | 0.08                  | (0.26) | 0.06                       | (0.23)  |
| Share female                         | 0.47   | (0.50) | 0.46                  | (0.50) | 0.43                       | (0.50)  |
| Share est. size < 10                 | 0.30   | (0.46) | 0.27                  | (0.45) | 0.25                       | (0.43)  |
| Share industrial firms               | 0.40   | (0.49) | 0.45                  | (0.50) | 0.36                       | (0.48)  |
| Mean log apprentice pay              | 3.25   | (0.30) | 3.27                  | (0.30) | 3.23                       | (0.31)  |
| Observations                         | 1427   |        | 7267                  |        | 12,479                     |         |
| <i>Workers (non-apprentices)</i>     |        |        |                       |        |                            |         |
| Share skilled workers                | 0.76   | (0.43) | 0.76                  | (0.43) | 0.76                       | (0.43)  |
| Mean log wages of<br>skilled workers | 4.52   | (0.41) | 4.55                  | (0.41) | 4.55                       | (0.41)  |
| Observations                         | 19,438 |        | 97,741                |        | 178,562                    |         |
| <i>Firms</i>                         |        |        |                       |        |                            |         |
| Share training firms                 | 0.25   | (0.43) | 0.26                  | (0.44) | 0.27                       | (0.44)  |
| Mean number of apprentices           |        |        |                       |        |                            |         |
| All firms                            | 0.66   | (3.13) | 0.79                  | (4.81) | 0.90                       | (5.49)  |
| Training firms                       | 2.68   | (5.87) | 3.04                  | (9.06) | 3.36                       | (10.24) |
| Observations                         | 2161   |        | 9177                  |        | 13,942                     |         |

Note: Described sample restrictions apply, weighted to adjust for disproportional selection of control regions.

impute values where wages are censored at the social security limit, using the standard technique proposed by Gartner (2005). Overall, we closely follow Dauth and Eppelsheimer (2020) in our data processing.

We observe data from 25,280 firms between 1993 and 2018, of which 2161 are located in the BR within a 30-minute travel radius to the next Swiss city and 9177 farther away in other AFMP regions. Within these firms, the data comprise information on about 21,173 apprentices, of which 1427 work in the BR and 7267 in other AFMP regions.

Table 1 shows that our approach yields a good match when examining the firm-level sample used in our analyses. The table provides descriptive statistics for apprentices, workers, and firms in the BR, other AFMP regions, and matched control regions. Compared to the matched control regions, apprentices in the BR are employed slightly more often in industrial firms (i.e., the primary sector, manufacturing, energy, or construction) and smaller establishments with fewer than 10 employees. However, with small differences, the matched control regions are comparable to the BR with respect to labor and apprenticeship market characteristics.

## 6. Results

In this section, 1. we test our two hypotheses and present the estimated effects of the AFMP on apprenticeship employment and wages. 2. We present the results of several robustness checks to test whether our results are sensitive to different operationalization or sampling decisions. 3. We explore heterogeneity of the reform effects with respect to firm characteristics and 4. provide results from further analyses of the underlying mechanisms.

### 6.1. Effect of the AFMP on training in the BR

With respect to our hypotheses derived in Section 3, we expect that the introduction of the AFMP and the resulting improved employment prospects across the border had two measurable effects: (H1) The number of apprentices increased. (H2) The apprentice wage did not

environment. Wenzelmann and Schönfeld (2022), for example, show that the public sector, on average, incurs much higher net costs per apprentice. Therefore, we exclude this sector from the analysis to avoid deluding the estimated effects.

necessarily increase. Given the institutional context of the AFMP, we expect that the effects may have been stronger after 2004 in the Free Movement Phase when all commuting restrictions were lifted.

We test the two hypotheses and our expectations concerning the reform phases by calculating yearly difference-in-differences for firms in the BR compared to the matched control regions, controlling for firm-fixed effects, according to Eq. (1). The panels of Fig. 4 show the estimated coefficients from interacting the firms' locations in the BR (or not) with the year-fixed effects for the log number of apprentices (Panel A), the probability to train apprentices (Panel B), and the log apprentice wage (Panel C). The results indicate that before the AFMP was announced in 1999 there are no significant effects of a location in the BR on apprentice numbers, the training probability, and wages. Hence, we do not suspect any pre-trends.<sup>20</sup>

In line with hypothesis (H1), our results confirm the positive effect of the AFMP on the number of apprentices in BR firms. Panel A of Fig. 4 shows that apprentice numbers in BR firms started to increase after 1999. In 2003, apprentice numbers increased sharply by 7% with respect to their 1998 level (see Table B.3). Given that BR firms in 1998 employed about 7135 apprentices (multiplying the observed number of apprentices in the 20% sample of BR firms by five, see Table 1), we hence by a back-of-the-envelope calculation estimate an increase of about 500 apprentices in 2003. The average training firm in the BR that initially employed 2.7 apprentices now employs nearly a third apprentice every year with an average of 2.9 apprentices in 2003. Although the effect was not significant at the 5%-significance level in early years, between 2004 and 2006, the figure shows that apprentice numbers increased over later years. Until 2018, the last year of our analysis horizon, apprentice numbers in the BR firms increased by 16% (about 1142 apprentices) with respect to their 1998 level. This also confirms our expectation that effects were stronger in the Free Movement period.

We also find the expected positive effect on the extensive margin in Panel B of Fig. 4, indicating that the number of firms employing at least one apprentice increased as well. The results show that the number of training firms started to increase after 1999 until 2010. In 2010, we estimate that the number of training firms was almost 5% higher than that in 1998 in the BR, meaning that about 133 additional firms trained

<sup>20</sup> Results for firms in other AFMP regions are discussed in Section 6.2 and indicate that BR firms were more affected by the AFMP than firms located farther away in other AFMP regions (see Table B.8).

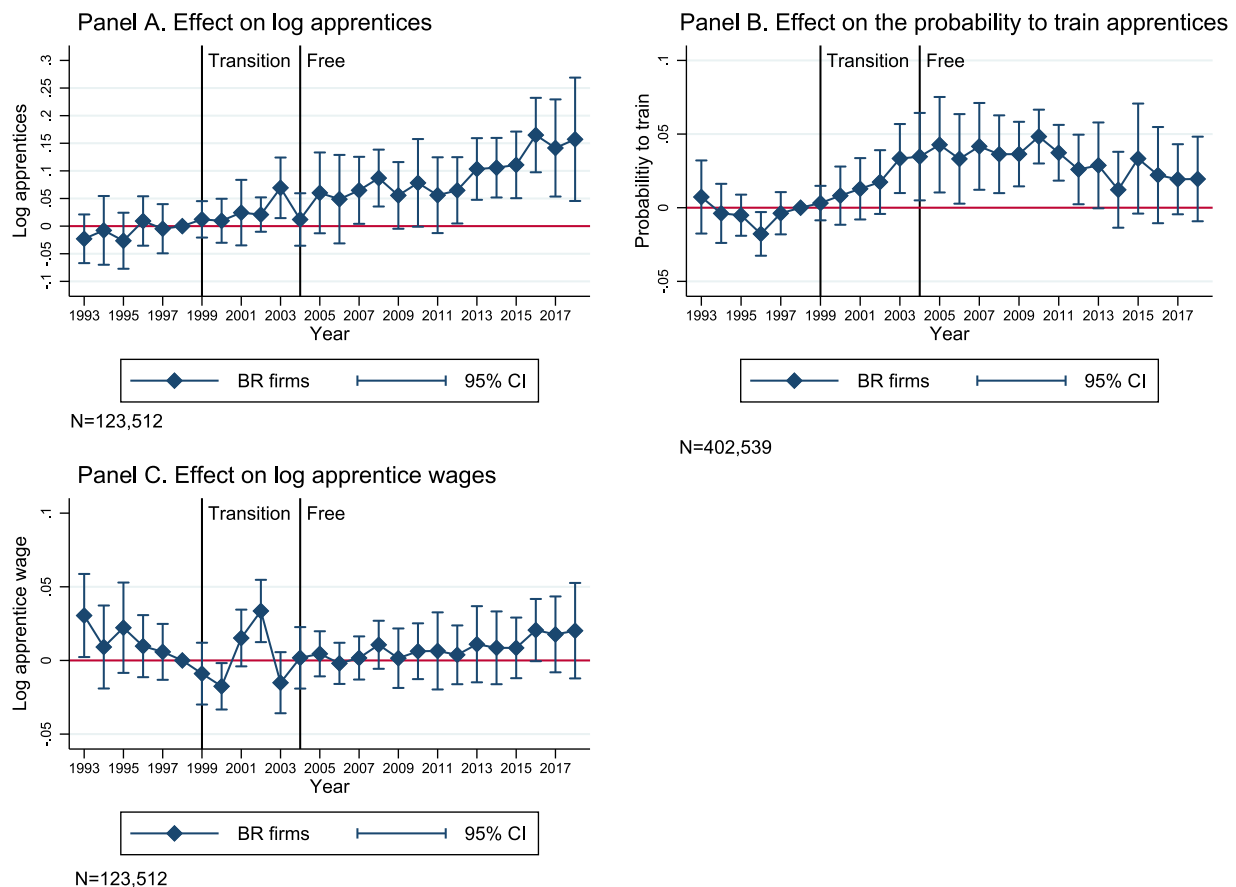


**Fig. 4.** Estimated reform effects on apprenticeship training.

Note: This figure shows coefficients of the interaction of firm location in BR with the years and the 95% confidence intervals from an estimation according to Eq. (1), accounting for firm-fixed effects, weighted to adjust for disproportional selection of control regions. Standard errors are clustered at the level of 62 municipal associations.

Source: BeH 1993–2018.

apprentices in 2010 (multiplying the observed number of training firms in the 20% sample of BR firms by 5, see Table 1).<sup>21</sup>

Furthermore, the results confirm the second hypothesis (H2) that there is no increase in apprentice wages. Panel C of Fig. 4 shows that after 2002 the effect on the apprentice wage of the AFMP was consistently insignificant. Following our theoretical considerations, this finding suggests that, at least in the Free Movement Period, apprentice supply must have increased, which kept apprentice wages from increasing while apprentice demand increased.

## 6.2. Robustness checks

We conduct several tests to evaluate the robustness of the results with respect to different aspects of our empirical approach.

**1. Region-level analysis.** So far, we presented firm-level results to show how apprentice employment changed in firms after the reform, but region-level analyses are also valuable because they capture the dynamics of the apprentice market as a whole, including, for example, firms' entries and exits. Therefore, we also run a regional-level analysis to see whether results differ, but find that they are qualitatively similar. For the regional-level analysis, we aggregate our data on the level of municipalities, conducting our analyses for the sum of apprentices

<sup>21</sup> We also estimate the coefficients using a logit model, which yields similar conclusions (see Table B.4).

and the average apprentice wage in the municipality, while controlling for municipality fixed effects. In line with our firm-level analysis, we find that the number of apprentices significantly increased after 2004 (see Table B.5, Column 1). However, these results also suggest that the average wages of apprentices even decreased in some years with respect to 1998 (see Table B.5, Column 2). This strongly supports our hypothesis that – next to apprentice demand – an increase in apprentice supply is an important mechanism because the increased supply relieved upward pressures on apprentice wages. Overall, the regional analysis confirms that the number of apprentices increased in the BR, while apprentice wages did not.

**2. Firm attrition.** Our sample consists only of firms that were already located in the BR before the reform. After the reform, however, firms may have moved or closed down. We, therefore, check whether our results are driven by firms that leave the market. We may introduce bias, for example, if firms that do not engage in training by coincidence also on average have shorter average longevity and therefore drop out of our analysis sample towards the end of our analysis horizon. To check this, we repeat our analyses using only stayer firms that we observe each year between 1993 and 2018 (approximately half of the full sample). Our results remain robust (see Table B.5, Column 3 and 4). We, therefore, conclude that attrition bias is negligible.

**3. Relative employment of apprentices.** By construction, our results on the effects on the log number of apprentices and log apprentice wages in firms only hold for firms that already trained before the AFMP, meaning in which wages are observed and apprentice numbers are not

zero in 1998. By looking at relative employment of apprentices instead of the log number of apprentices in firms, which can also take values of zero, we can also include non-training firms in our analysis. Therefore, we test whether we observe an increase in the number of apprentices relative to skilled workers in firms. Table B.5, Column 5, shows that this ratio significantly increased in BR firms after 2004. Hence, the relative employment of apprentices increased across all firms in the BR in the Free Movement Period.<sup>22</sup>

4. *Weighting.* So far, we only weight to account for the disproportional selection of the matched control regions. Therefore, we assess the robustness of our results when weighting by firm size and regional population. When weighting by population size of the municipal association, results are robust (see Table B.6, Columns 1 and 2). When weighting by firm size, point estimates are also very similar to those that are not weighted by firm size. However, standard errors become larger (see Table B.6, Columns 3 and 4). A reason for this is that more weight is put on larger firms, which, however, represent a smaller proportion of the apprenticeship market. Smaller firms with fewer than 10 employees trained about 60% of all apprentices in 1998 in the studied regions (see Table 1). Weighting by firm size, hence, gives more weight to firms that train less often and may have also been less responsive to the AFMP. Overall, however, weighting by firm size supports an increase in the number of apprentices after the AFMP, while apprentice wages remained unchanged.

5. *Definition of the BR.* So far, we defined the BR as regions from which commute to the next Swiss city is possible within 30 min travel time. We now test the extent to which our results are sensitive to this definition. For this, we conduct two robustness checks. First, we test different categorizations of the BR. We estimate average effects of the AFMP in the Transition and Free Movement period at any possible definition of the BR between 15 and 45 min of maximal travel time. Specifically, we regress the log number of apprentices and the log apprentice wage on an indicator of the location of the firm in the BR given a specific cut-off, an indicator of the year being in the Transition (199–2003) or the Free Movement period (2004–2018), and the interaction of the two indicators,<sup>23</sup> and repeat this analysis using different to categorize firms into BR firms. Fig. A.3 shows that for the effect on apprentice numbers, the exact definition of the BR does not matter. For apprentice wages (see Fig. A.4), we find that defining the BR as regions that lie within 17 min of the next Swiss city would indicate positive effects on apprentice wages in the BR in the Free Movement period. This could indicate that within these bounds apprentice supply did not increase enough to meet apprentice demand and counteract upward wage pressure. However, results in this region could also simply be driven by specific firms. Any other definition of the BR beyond 17 min of travel time confirms an insignificant effect on apprentice wages.

Second, we conduct similar analyses for the average ATTs in the Transition and Free Movement period using a continuous treatment

measure instead of categorizing firms. Table B.7 presents the results of the estimations using the log travel time from the firm's location by municipality as treatment measure. Again, the results support our findings that a firm located farther away from the border is associated with lower apprentice numbers after the introduction of the AFMP and higher apprentice wages in the Transition period. Considering both robustness checks, we conclude that our results do not depend on the exact definition of the BR with respect to its maximal distance from the Swiss border.

6. *Comparison to firms in other AFMP regions.* We have only looked at the results for firms in the BR. Now, we also compare them to firms in other AFMP regions that are farther away from the border and are therefore not really border regions to see whether the reform affected firms in the direct BR to a greater extent. First, we conducted analyses for firms located in other AFMP regions. The effect on apprentice numbers is smaller than for BR firms, however we also detect pre-trends, which makes an interpretation of these results difficult (see Table B.8, Column 1). We find that apprentice wages in these firms are unaffected by the reform (see Table B.8, Column 2). Second, to further assess whether BR firms were more affected by the reform than firms in other AFMP regions, we additionally check, whether our results are robust when comparing the BR to the other AFMP regions instead of the matched control regions. In comparison to the other AFMP regions, we find that apprentice numbers increase in the BR already significantly in the Transition period by about 5% (see Table B.8, Column 3), hence similarly in magnitude to the increase with respect to the matched control regions in the Free Movement period (see Table B.3, Column 1). In the Free Movement period, numbers only significantly increased further after 2013 relative to other AFMP regions. Also similar to the comparison to the matched control regions, apprentice wages appear unaffected by the reform in the BR relative to other AFMP regions (see Table B.8, Column 4). Overall, we conclude that the BR firms were significantly more affected by the AFMP than firms in other AFMP regions.

7. *Concurrent Trade liberalizations.* At the same time as the AFMP, Switzerland also negotiated trade liberalizations with its neighboring countries as part of the Mutual Recognition Agreement (MRA). Hence, positive effects on apprentice numbers could reflect an increase in product demand through increased trade. To explore this, we follow Beerli et al. (2021) and check whether our results are driven by sectors that were heavily impacted by the MRA. According to Bühler et al. (2013), these were manufacturing of furniture, manufacturing of other goods (jewelry, toys, etc.), wholesale, retail, and sale of motor vehicles. When we exclude firms that belong to these sectors our results do not change (see Table B.9), even though the excluded sectors are traditional sectors for apprenticeship training. Our results, hence, reflect changes in the apprenticeship market in response to the opening of the border instead of increased trade with Switzerland.

8. *Concurrent school reform.* All of the AFMP and control regions were subject to the so called G8 school reform which shortened the high school track leading to a university entrance certificate (Abitur) from 13 to 12 years of schooling. The reform entailed a year without any graduates from this track, followed by a year with two graduate cohorts. The double cohort years where 2011 in Lower Saxony and Bavaria, 2012 in Baden-Württemberg, 2013 in Northrhine-Westphalia and Hesse, and 2016 in Rhineland-Palatinate. Muehleman et al. (2022) showed that the reform did not affect apprentice wages, but had a positive effect of 7% on the number of apprenticeship contracts with graduates with Abitur. To test, whether this reform affects our results, we perform two robustness checks. First, we control for the log number of school leavers in a year in the firm's district (see Table B.10, Column 1 and 2). In years of double cohorts, this number temporarily increased. Unfortunately, data on school leavers is only available from 1995 onward, so that we lose pre-reform observations when conducting this analysis. Second, we, therefore, perform another robustness check where we control for a dummy variable indicating

<sup>22</sup> Alternatively, it would also be possible to test to what extent the number of apprentices scaled by firm size in 1998, before the reform, increased. Although standard errors get very large in this estimation, the results still indicate increasing point estimates for the scaled number of apprentices (see Table B.5, Column 6). Hence, these results largely support our main conclusions.

<sup>23</sup> For this purpose, we adapt Eq. (1):

$$Y_{it} = \alpha + \zeta_i + \tau_t + \lambda_4 \text{Transition}_t + \lambda_2 \text{Free}_t + \lambda_3 \text{BR}_i(x) + \lambda_4 \text{other AFMP}_i(x) + \gamma_1 \text{Transition}_t \times \text{BR}_i(x) + \gamma_2 \text{Transition}_t \times \text{other AFMP}_i(x) + \gamma_3 \text{Free}_t \times \text{BR}_i(x) + \gamma_4 \text{Free}_t \times \text{other AFMP}_i(x) + \mu_{it}, \quad (2)$$

where Transition is an indicator of  $t \in [1999, 2003]$ , Free is an indicator of  $t \in [2004, 2018]$ , and  $\mu$  is an error term. The categorization of BR and other AFMP is subject to the cut-off travel time  $x$ . We are interested in the coefficients  $\gamma_1$  and  $\gamma_3$ , which capture the average ATT in the Transition and Free Movement period of the reform, respectively, in the BR given  $x$ .

the year of the double cohort given the federal state where the firm is located (Table B.10, Column 3 and 4). Both robustness checks produce results that are very close to our main results and, hence, show that our results are not driven by the G8 school reform.

Overall, our tests show that the main results are robust to different specifications and samples.

### 6.3. Effect heterogeneity

To analyze whether the AFMP affected some firms more than others, we explore heterogeneities of the observed effects by several firm characteristics. First, we test, whether apprentice numbers increased stronger in larger than smaller firms. Although training firms are mostly smaller, larger firms may have larger labor demands and a greater capacity to employ extra apprentices. Splitting the sample into firms with at most 10 employees and apprentices (see Table B.11, Column 1) and those with a higher number (see Column 2) in 1998, we find that in large establishments apprentice numbers started increasing right away after the reform was implemented, while in small firms the numbers only started increasing after 2004. However, overall, we do not find clear differences between the two firm types.

Second, we conducted our analyses for industrial (see Table B.11, Column 3) and service sector firms (see Column 4) separately to test whether the AFMP disproportionately affected one of these sectors of the economy. There are small signs that the number of apprentices in service sector firms may have already increased in the Transition period of the reform, while in industrial firms the increase only started after 2004. However, overall, we find that apprenticeship training was affected by the AFMP in both sectors without clear differences. Third, we test whether the number of apprentices increased mostly in firms that initially had a high demand for skilled workers. If apprentices serve as a substitute for skilled workers, their demand should have only increased in firms that initially employed skilled workers extensively. Hence, we explore whether apprentice numbers increased only in firms that in 1998 employed an above average share of skilled workers (with a completed apprenticeship as opposed to no formal education and tertiary education, Table B.11, Column 5), or also in those that employed an average or lower share (see Column 6). Our results clearly show that the number of apprentices only increased in firms that heavily relied on skilled work before the reform. Firms that have lower demands for skilled work did not increase their training. This suggests that the reform increased apprenticeship training mostly in firms that could use them as substitute for their non-apprentice workforce.

In all of the above analyses, we do not find any differences in the effect on apprentice wages. Table B.12 shows that the effect of the AFMP on apprentice wages is insignificant in any case.

### 6.4. Further analyses

We conduct further analyses to shed light on the mechanisms leading to the observed effects. First, we present some indications that the positive effect on the number of apprentices is likely driven by the increased demand from firms and at the same time an increase in the supply of apprentices (adolescents applying for apprenticeship positions). Unfortunately, information on apprenticeship supply and demand is very limited. To nevertheless gain some insight on the underlying mechanisms, we use data from the Apprenticeship Market Statistics by the Federal Employment Agency (BA) that report on offered apprenticeship positions since 2006 and apprenticeship applicants since 2008 on the district level. Although this is well after the AFMP was implemented, we believe that it is informative, as we observe significant positive effects on apprentice numbers mostly after 2007 (see Fig. 4). In Fig. 5, we contrast the aggregate development of the matched control region's districts with the districts located in the BR. Panel A shows the development in offered apprenticeship positions that were registered by firms with the BA for the two regions (apprentice

demand). Offered positions decreased between 2006 and 2009 and then increased thereafter. Since 2006, the developments in positions has been similar in the BR and control region districts.

Panel B of Fig. 5 shows the development in the apprenticeship applicants that registered with the BA as a share of school leavers (apprentice supply). Here, we see that the number of applicants more or less steadily increased until 2017 in the BR districts, while the applicant share in the control regions decreased after 2012. The Figure lends support that both the numbers of offered apprenticeships as well as the share of apprenticeship applicants increased, meaning that apprentice supply increased alongside apprentice demand. This supports the hypothesis that apprenticeships have become more attractive to young school leavers in the BR.

Second, we also check whether the insignificant effects of the AFMP on apprentice wages might only reflect changes in the composition of apprenticeships. This could occur when the occupational composition changes towards low-wage apprenticeships. In this case, we might be unable to detect a positive effect of the AFMP on apprentice wages, because apprentices are now employed in different occupations. However, our results do not change, when we control for occupational composition in the firm in the apprentice wage estimation (see Table B.13, Column 1). Also, Table B.14 shows that the changes in the occupational composition of apprenticeships in the BR are small and do not coherently fit the pattern of increasing apprentice employment in low-wage occupations. Overall, we find no evidence that any composition effects disguise apprentice wage effects and render them insignificant; instead, it is more likely caused by a shift in apprentice supply which counteracts the upward pressure on apprentice wages.

Finally, to substantiate the argument that the reform tightened the labor market for skilled workers, we examine its effects on skilled worker separations and employment levels on the German side of the border. First, we see that the yearly number of separations of skilled workers from border region firms significantly increased after the reform (Fig. 6, Panel A), indicating that the labor market for skilled labor substantially tightened for firms in the border region. This result is in line with Fig. 3 which documents that the large outflow of workers as CBWs almost exclusively affected the BR. This suggests that BR firms faced an increased need to replace the lost skilled workers by either hiring new skilled workers (which became more difficult due to the outflow of workers to Switzerland) or by substituting skilled worker positions with additional apprentices.

Second, the stock of skilled workers in BR firms did not decrease relative to the control regions, but slowly increased in the Free Movement period (see Fig. 6, Panel B). This somewhat puzzling result can be explained by two mechanisms (a. an increase in product demand and b. a change in workforce composition), which are all in line with our supply and demand model and with our empirical observation of increasing numbers of apprentices after the reform.

*a. Product demand.* It seems reasonable to assume that product demand may have increased given the substantially higher earnings of the CBWs, i.e. skilled workers living on the German side and working across the border (CBWs) in Switzerland. These substantially higher earnings lead to increased product demand in their German home regions, which in turn leads to increased labor demand. Part of the positive effect on the number of apprentices may also be attributable to a general increase in labor demand.<sup>24</sup>

*b. Workforce composition.* Firms may have increased their demand for skilled workers to compensate for a lower average productivity of

<sup>24</sup> It is also possible that labor demand increased due to the concurrent introduction of the Trade Agreement MRA. We follow the empirical approach of Bühler et al. (2013) to rule out that the observed effects are driven by trade rather than the AFMP. By excluding the industries that Bühler et al. (2013) highlight from the analysis, we find the same positive and significant effect on skilled worker employment in the border region (see Table B.9, Column 3).

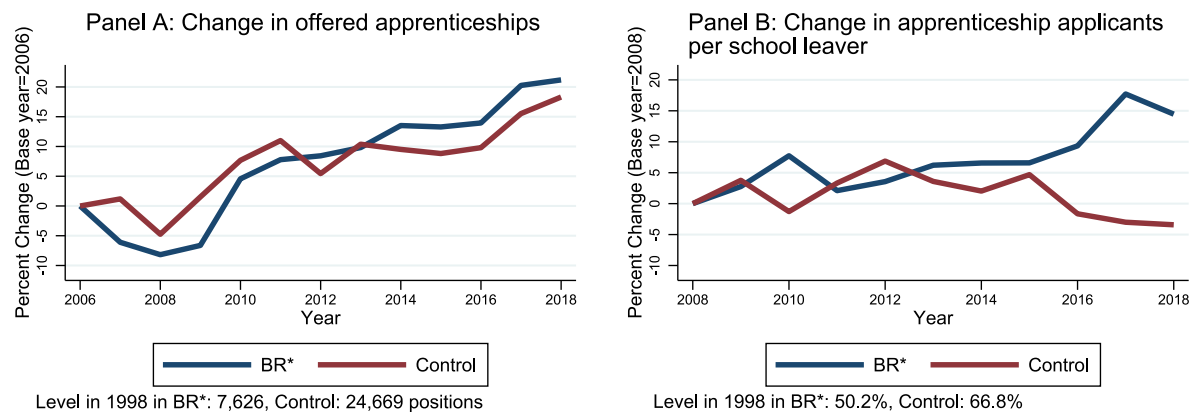


**Fig. 5.** Change in offered apprenticeships and applicants.

Note: Panel A shows offered apprenticeships that are registered with the Federal Employment Agency, increase in % from base year 2006. Panel B shows applicants that registered with the Federal Employment Agency divided by the number of school leavers, increase in % from base year 2008. BR\* refers to districts that include BR municipalities.

Source: Apprenticeship market Statistics of the Federal Employment Agency 2006–2018.

workers who stayed in the German labor market in comparison to the leavers after the border opened. Results on the wages of skilled workers provide some support for this mechanism. They show that although average wages within firms declined in the Transition Phase (see Fig. 6, Panel C), the wages of stayers did not decrease (see Fig. 6, Panel D). This lends support that the decrease in average wages is driven by changes in workforce composition, that is due to more productive workers leaving and less productive ones staying.

## 7. Conclusion

This study investigates how improved employment prospects across the border affect training adjustments in firms in the sending country, through facilitating international mobility and particularly through the resulting skill shortages owing to the outflow of workers. We focus on middle skilled workers who are trained in apprenticeship training programs by German firms. Our analysis builds on a reform that opened the Swiss border for cross-border commute and led to a considerable exogenous outflow of workers from the German border regions, as they started to commute in large numbers to Switzerland, motivated by substantially higher wages in the neighboring country.

For the empirical analysis, we applied a DiD framework exploiting the variation in the treatment intensity (i.e., the size of the outflow of workers from the region) by the location of the firm in terms of travel time to the next Swiss city. We find a significant increase in the number of apprenticeships in training firms although apprenticeship wages did not increase. Although our results indicate that the effect size is mostly driven by smaller firms, results with firm weighted data that put more weights on larger firms still support our main results.

What seems like a puzzle can be explained based on a very simple graphical model of supply and demand, suggesting that the results are due to a mix of supply- and demand-side adjustments: On the demand side, firms may increase their demand for apprentices to address the increased separations of skilled workers. Companies had to look for alternative workers, which boosted the hiring of apprentices because they can be employed to do skilled workers' tasks during their training period and because they increase the pool of skilled workers after the training period. But because apprentices are initially less productive than skilled workers, proportionally more apprentices are needed than the number of skilled workers who have left. And if the local economy has been boosted by increased product demand, companies will then employ these apprentices after the training period, leading to an increase in skilled worker employment.

On the supply side, apprenticeship applicants have higher incentives to apply for apprenticeship training positions because after border opening, their expected wages after graduation have increased substantially due to the border opening and the much higher skilled worker wages across the border in Switzerland. So, when weighing low short-run training wages against substantially higher long-run worker wages across the border, adolescents who live in the border region and have the option to just work on the other side of the border within a typical commuting time of 30 min may be more likely to start an apprenticeship compared to before the border opening. An indication for the increase in apprenticeship interest is the increase in the apprenticeship applicant share among all school leavers in the border regions after the AFMP.

Our study contributes to the literature on the effects of migration of workers between industrialized countries, focusing on the effects on training in firms in the sending country, which have not yet been analyzed in the literature. The results indicate that the AFMP's positive effects on apprentice training in the sending country, Germany, of 7% in 2003 and of up to 16% in 2018, substantially exceeded its negative effects in the receiving country, Switzerland. While [Aeppli and Kuhn \(2021\)](#) find a negative effect of 2% on the number of apprentices in Switzerland, [Oswald-Egg and Siegenthaler \(2023\)](#) find no significant effects on the apprenticeship market at all. Our evidence suggests that this discrepancy may be attributable to the supply-side adjustments of the apprenticeship market in the German border region that enabled a stronger increase in apprenticeships after the AFMP was introduced.

Our results have implications for both policy and practice. Investing in apprenticeships has been shown to be a sustainable way for firms to secure their skill supply ([Muehlemann and Wolter, 2014](#)). However, the German training market is suffering from excess demand for apprentices. Consequently, several industries lack young workers to meet the skill demands of firms (cf. [Dummert et al., 2019](#); [Muehlemann et al., 2020](#); [BIBB, 2024](#)). The problem is that firms cannot hire enough apprentices to solve the problem, so incentives or benefits on the adolescents' side are too weak. Our results suggest that substantial increases in skilled worker wages increase the attractiveness of apprenticeships, which may lead to an increase in apprentices supply. Thus, attractive skilled worker wages and other benefits seem to be one of the key mechanisms for attracting more applicants to the German apprenticeship market — or other training markets where the supply of trainees may fall short because of insufficient wage opportunities after training. Improved skilled worker wages may, thus, not only reduce skilled worker shortages because they attract experienced skilled

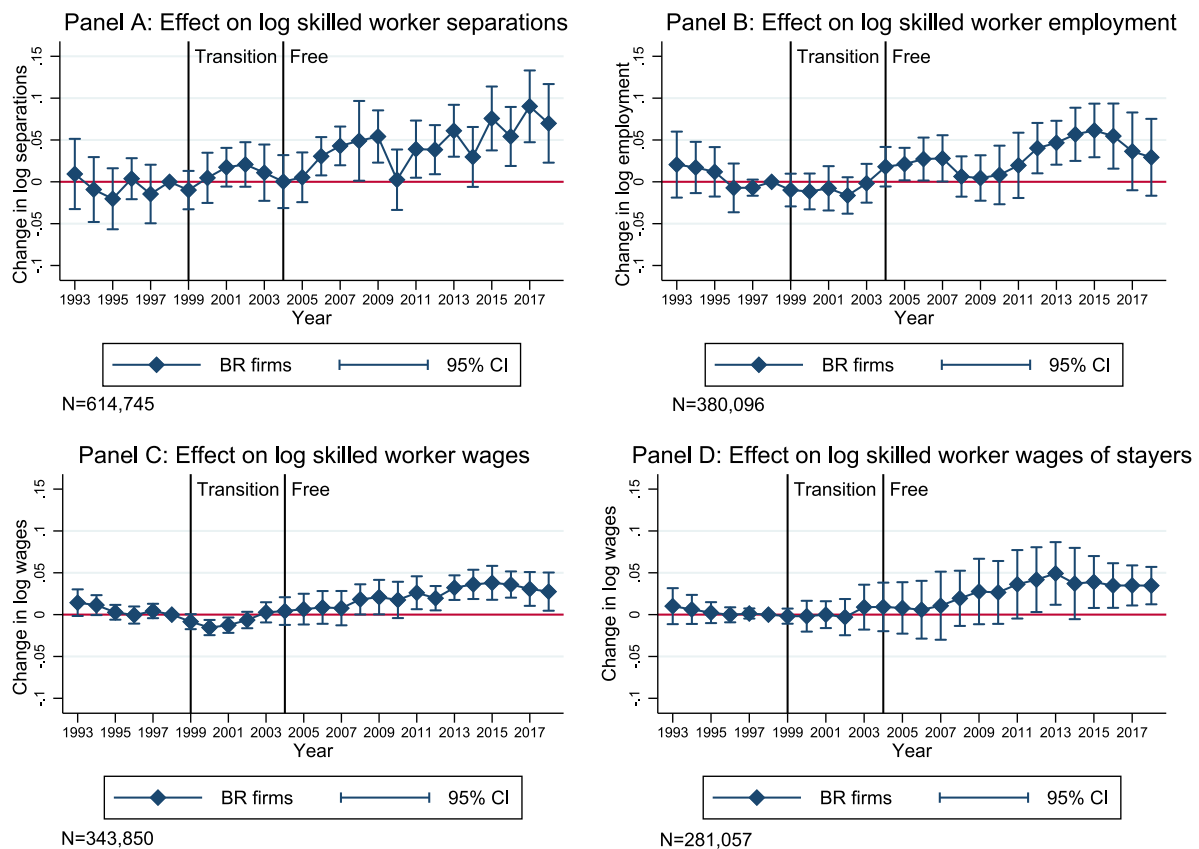


**Fig. 6.** Estimated reform effects for skilled workers.

Note: This figure shows coefficients of the interaction of firm location in BR with the years and the 95% confidence intervals from an estimation according to Eq. (1), accounting for firm-fixed effects, weighted to adjust for disproportional selection of control regions. Panel A shows results on log separations of skilled workers in firms using BHP data, where skilled work is defined according to Blossfeld (1985). Standard errors are clustered at the level of 62 municipal associations. Source: BeH and BHP 1993–2018.

workers. They may also reduce these shortages because they attract more adolescents to such careers and, thus, may also help to sustainably solve shortages of skilled workers in the long run.

Our research findings could be generalized in two important ways. They can be expanded beyond Germany and Switzerland to other nations facing similar dynamics in skilled labor markets. The analytical approach can be applied to many countries experiencing brain drain due to better opportunities of skilled workers abroad, impacting their domestic labor supply. The key parameters – such as the wage gap between sending and receiving countries, the size of worker flows, and post-training benefits – could be adapted for different countries and many industries in which companies are investing in workers' training in the form of apprenticeship training or similar middle skill training measures. However, our results also indicate that while brain drain can present challenges, it may also yield brain gains because it encourages investments in education and increases the supply of skilled workers in the home country. Moreover, our research findings could be generalized to other sectors and other levels of education with similar training structures, in which part of the training takes place while working on the job in firms or public organizations (e.g., PhD candidates, auditors, lawyers, or teachers). The academic labor market, for example, employs a similar apprenticeship-style training system in the form of PhD programs where doctoral candidates work for low wages or grants to receive an education in a university while working with established researchers on their research projects. Brain drain is a well-documented phenomenon in academia as well, and our results lend some support that it is the labor market opportunities after

finishing the training phase (in combination with wages during the training phase) at home or abroad that determine the attractiveness of PhD training for individuals and universities alike. These examples show that our findings are generalizable in many ways and, hence, go far beyond the German–Swiss border regions or the example of apprenticeship training programs.

#### CRediT authorship contribution statement

**Caroline Neuber-Pohl:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Damiano Pregaldini:** Writing – original draft, Visualization, Data curation, Conceptualization. **Uschi Backes-Gellner:** Writing – review & editing, Supervision, Resources, Conceptualization. **Sandra Dummert:** Writing – review & editing, Validation, Data curation. **Harald Pfeifer:** Supervision, Resources, Conceptualization.

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## 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. Figures

See Figs. A.1–A.4.

## Appendix B. Tables

See Tables B.1–B.14.

## Data availability

The analyses use administrative data of the Institute for Employment Research (IAB) [IAB Beschäftigtenhistorik (BeH) V10.06.00-202012] and the Establishment History Panel (BHP) 7519 v2. The data are social security data with administrative origin which are processed and kept by IAB, Regensburger Str. 104, D-90478 Nürnberg, iab@iab.de, phone:+49 911 1790, according to the German Social Code III. There are certain legal restrictions due to the protection of data privacy. The data contain sensitive information and therefore are subject to the confidentiality regulations of the German Social Code (Book I, Sect. 35, Paragraph 1). The raw data, evaluation programs, and results have been archived by IAB in accordance with good scientific practice. Evaluation programs and results can be found in the Reproduction package. If you wish to access the full data for replication purposes, please contact Sandra Dummert (Sandra.dummert@iab.de). Please visit <https://iab.de/en/facts-and-figures-2/data-access-for-replication-purposes/>.

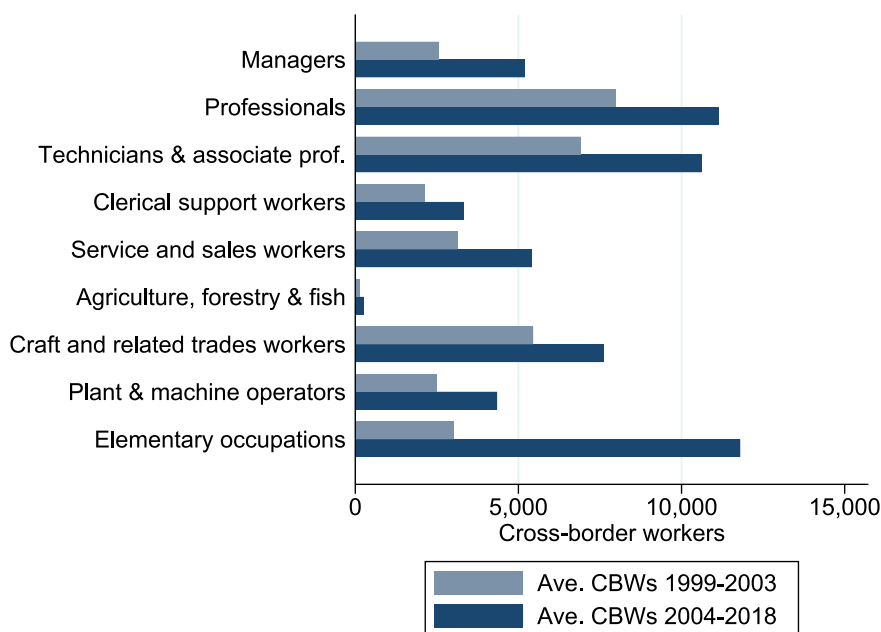


**Fig. A.1.** Yearly average of registered cross-border workers by occupation in the Transition Phase and the Free Movement Phase.  
Source: Cross Border Commute Statistics (CBCS) 1999–2018.

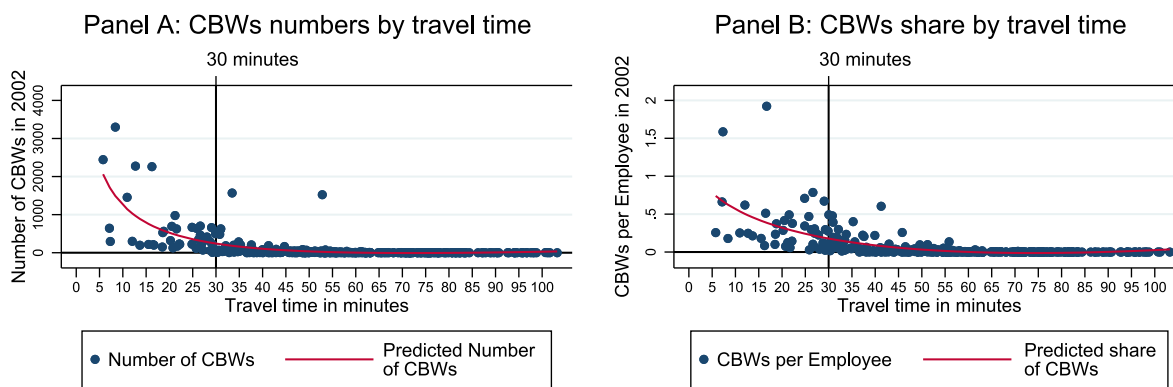


**Fig. A.2.** CBWs in 2002 in municipalities of the AFMP regions by travel time from municipality to the next Swiss city.  
Note: The CBWs share is computed as the relation between CBWs numbers to employees subject to social security contributions.  
Source: Cross Border Commute Statistics (CBCS) 2002, Employment Statistics of the Federal Employment Agency (BA) 2002.

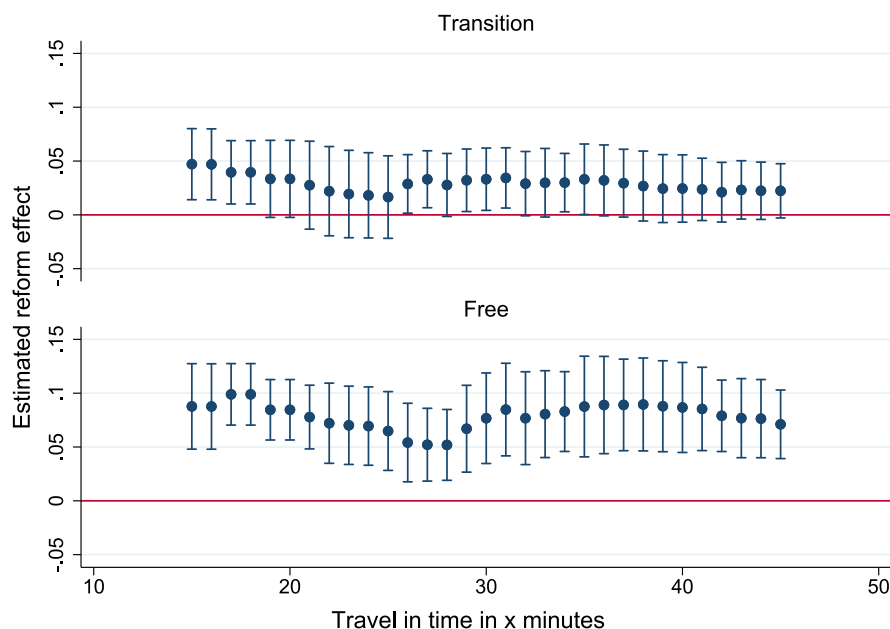


**Fig. A.3.** Estimated average reform effects in the Transition and Free Movement Period on log. number of apprentices by BR definition.

Note: This figure shows coefficients of the interaction of firm location in BR with reform phase indicators and the 95% confidence intervals, accounting for firm-fixed effects, weighted to adjust for disproportional selection of control regions. Standard errors are clustered at the level of 62 municipal associations. Reform phases: Transition Phase 1999–2003, Free Movement Phase 2004–2018, reference years 1993–1998. BR defined by the cut-off amount of travel time in minutes to the next Swiss city. N = 123,512.

Source: BeH 1993–2018.

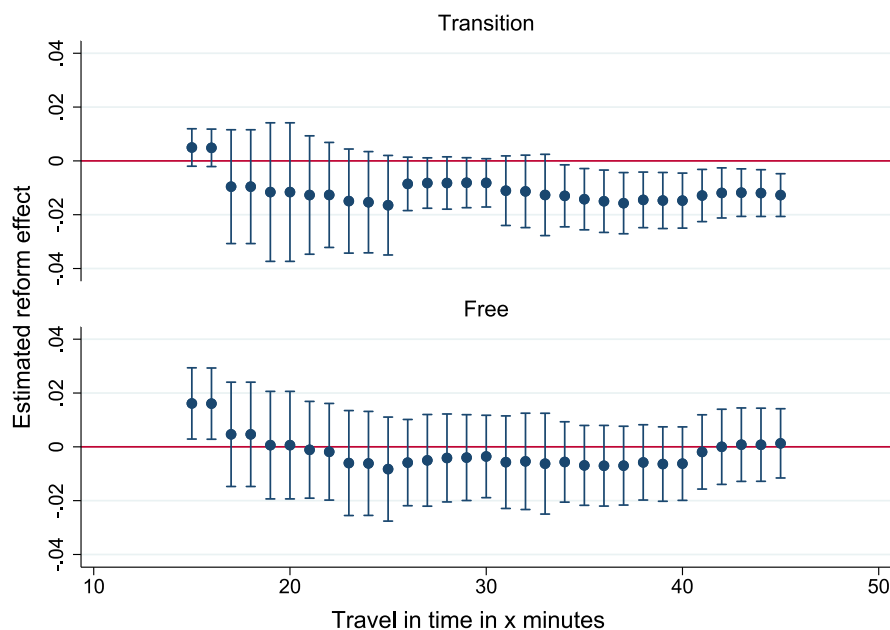


**Fig. A.4.** Estimated average reform effects in the Transition and Free Movement Period on log. apprentice wages by BR definition.

Note: This figure shows coefficients of the interaction of firm location in BR with reform phase indicators and the 95% confidence intervals, accounting for firm-fixed effects, weighted to adjust for disproportional selection of control regions. Standard errors are clustered at the level of 62 municipal associations. Reform phases: Transition Phase 1999–2003, Free Movement Phase 2004–2018, reference years 1993–1998. BR defined by the cut-off amount of travel time in minutes to the next Swiss city. N = 123,512.

Source: BeH 1993–2018.

**Table B.1**

Worker wages in Switzerland and Germany by ISCO-08 occupation in 1999–2002 in Euro in prices of 2000.

Source: SLFS and SIAB 1999–2002.

| Occupational field                                 | Switzerland                    | Germany                          |
|----------------------------------------------------|--------------------------------|----------------------------------|
| Managers                                           | 6704.56<br>(5625.24)<br>[2836] | 3044.47<br>(2092.71)<br>[19,401] |
| Professionals                                      | 5718.79<br>(5267.57)<br>[6394] | 2929.95<br>(1865.70)<br>[38,709] |
| Technicians and associate professionals            | 4643.1<br>(4220.43)<br>[6865]  | 2738<br>(1686.83)<br>[42,886]    |
| Clerical support workers                           | 3575.64<br>(3446.68)<br>[4574] | 2811.97<br>(1734.44)<br>[12,640] |
| Services and sales workers                         | 3199.07<br>(2949.34)<br>[3748] | 2124.83<br>(1297.22)<br>[9460]   |
| Skilled agricultural, forestry and fishery workers | 2493.55<br>(2519.66)<br>[465]  | 2025.37<br>(1018.28)<br>[606]    |
| Craft and related trades workers                   | 3215.24<br>(3267.02)<br>[5592] | 2753.92<br>(1576.11)<br>[20,377] |
| Plant and machine operators and assemblers         | 3554.22<br>(3433.04)<br>[1754] | 2651.51<br>(1606.26)<br>[15,629] |
| Elementary occupations                             | 2782.22<br>(3044.49)<br>[526]  | 2405.58<br>(1359.67)<br>[28,084] |

Note: Mean average wages of workers excluding apprentices by ISCO-08 first digit occupational field, Swiss wages converted from Swiss Francs to Euro using the 2002 average exchange rate, standard deviation in parentheses and number of observations in squared brackets.

**Table B.2**

Comparison of district characteristics by location in 1998.

Source: BHP 1998.

|                                    | Border region         | Matched districts      | West Germany             |
|------------------------------------|-----------------------|------------------------|--------------------------|
| <i>Population</i>                  |                       |                        |                          |
| Mean population size               | 198,347<br>(54 225.8) | 257,254<br>(153,639.9) | 409,948.2<br>(388,039.5) |
| Mean population density            | 357.9<br>(396.0)      | 433.7<br>(335.8)       | 1027.4<br>(933.9)        |
| Mean unemployment rate             | 6.970<br>(1.420)      | 10.468<br>(2.293)      | 10.422<br>(2.581)        |
| Mean commuter balance              | 1.090<br>(17.242)     | 2.992<br>(24.644)      | 2.140<br>(29.970)        |
| <i>Firms</i>                       |                       |                        |                          |
| Mean number of firms               | 2612.3<br>(693.4)     | 2899.3<br>(1639.9)     | 4994.6<br>(5128.5)       |
| Share training firms               | 0.240<br>(0.019)      | 0.246<br>(0.030)       | 0.228<br>(0.042)         |
| <i>Workers</i>                     |                       |                        |                          |
| Mean employment level (FTE)        | 25,350.4<br>(8011.1)  | 32,565.6<br>(17,592.1) | 63,440.8<br>(72,442.4)   |
| Mean number of apprentices         | 1665.1<br>(412.8)     | 2064.8<br>(1034.9)     | 3338.5<br>(3282.6)       |
| Share of apprentices               | 0.070<br>(0.009)      | 0.067<br>(0.013)       | 0.063<br>(0.017)         |
| Share untrained workers            | 0.169<br>(0.028)      | 0.156<br>(0.030)       | 0.139<br>(0.026)         |
| Share trained workers              | 0.764<br>(0.032)      | 0.766<br>(0.051)       | 0.783<br>(0.052)         |
| Share workers with tertiary degree | 0.100<br>(0.038)      | 0.110<br>(0.056)       | 0.103<br>(0.049)         |
| Share manufacturing workers        | 0.434<br>(0.115)      | 0.359<br>(0.114)       | 0.322<br>(0.139)         |

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Table B.2 (continued).

|                      | Border<br>region | Matched<br>districts | West<br>Germany  |
|----------------------|------------------|----------------------|------------------|
| Mean log Wages       | 83.7<br>(8.2)    | 82.4<br>(9.0)        | 85.9<br>(11.5)   |
| Share censored wages | 0.073<br>(0.031) | 0.067<br>(0.037)     | 0.087<br>(0.052) |

Note: Here, West Germany only considers municipalities that are located at least three hours by car away from the next Swiss city. Weighted by employment level of district.

Table B.3

Estimated reform effects on training firms.

Source: BeH 1993–2018.

|                  | (1)<br>Log apprentice<br>number |         | (2)<br>Log apprentice<br>wages |         | (3)<br>Probability to<br>train apprentices |         |
|------------------|---------------------------------|---------|--------------------------------|---------|--------------------------------------------|---------|
|                  | Coef.                           | SE      | Coef.                          | SE      | Coef.                                      | SE      |
| 1993             | −0.023                          | (0.022) | 0.031**                        | (0.014) | 0.007                                      | (0.012) |
| 1994             | −0.008                          | (0.031) | 0.009                          | (0.014) | −0.004                                     | (0.010) |
| 1995             | −0.026                          | (0.025) | 0.022                          | (0.015) | −0.005                                     | (0.007) |
| 1996             | 0.009                           | (0.022) | 0.010                          | (0.011) | −0.018**                                   | (0.007) |
| 1997             | −0.005                          | (0.022) | 0.006                          | (0.009) | −0.004                                     | (0.007) |
| 1998 (reference) |                                 |         |                                |         |                                            |         |
| 1999             | 0.012                           | (0.016) | −0.009                         | (0.010) | 0.003                                      | (0.006) |
| 2000             | 0.010                           | (0.020) | −0.018**                       | (0.008) | 0.008                                      | (0.010) |
| 2001             | 0.024                           | (0.030) | 0.015                          | (0.010) | 0.013                                      | (0.010) |
| 2002             | 0.021                           | (0.016) | 0.034***                       | (0.011) | 0.017                                      | (0.011) |
| 2003             | 0.069**                         | (0.027) | −0.015                         | (0.010) | 0.033***                                   | (0.012) |
| 2004             | 0.012                           | (0.024) | 0.002                          | (0.010) | 0.035**                                    | (0.015) |
| 2005             | 0.060                           | (0.037) | 0.004                          | (0.008) | 0.043**                                    | (0.016) |
| 2006             | 0.049                           | (0.040) | −0.002                         | (0.007) | 0.033**                                    | (0.015) |
| 2007             | 0.065**                         | (0.030) | 0.002                          | (0.007) | 0.042***                                   | (0.015) |
| 2008             | 0.087***                        | (0.026) | 0.011                          | (0.008) | 0.036***                                   | (0.013) |
| 2009             | 0.056*                          | (0.030) | 0.002                          | (0.010) | 0.036***                                   | (0.011) |
| 2010             | 0.078*                          | (0.040) | 0.006                          | (0.009) | 0.048***                                   | (0.009) |
| 2011             | 0.056                           | (0.034) | 0.006                          | (0.013) | 0.037***                                   | (0.009) |
| 2012             | 0.065**                         | (0.030) | 0.004                          | (0.010) | 0.026**                                    | (0.012) |
| 2013             | 0.103***                        | (0.028) | 0.011                          | (0.013) | 0.029*                                     | (0.015) |
| 2014             | 0.106***                        | (0.027) | 0.009                          | (0.012) | 0.012                                      | (0.013) |
| 2015             | 0.111***                        | (0.030) | 0.009                          | (0.010) | 0.033*                                     | (0.019) |
| 2016             | 0.165***                        | (0.034) | 0.021*                         | (0.011) | 0.022                                      | (0.016) |
| 2017             | 0.142***                        | (0.044) | 0.018                          | (0.013) | 0.019                                      | (0.012) |
| 2018             | 0.157***                        | (0.056) | 0.020                          | (0.016) | 0.020                                      | (0.014) |
| Observations     | 123,512                         |         | 123,512                        |         | 402,539                                    |         |

Note: \*p < 0.1, \*\*p < 0.05, \*\*\*p < 0.01, coefficients of the interaction of firm location in BR with the years from an estimation according to Eq. (1), accounting for firm-fixed effects, weighted to adjust for disproportional selection of control regions. Standard errors in parentheses are clustered at the level of 62 municipal associations.

Table B.4

Estimated reform effects on the probability to train using fixed effects logit.

Source: BeH 1993–2018.

|                  | (1)<br>Probability to train apprentices |         |
|------------------|-----------------------------------------|---------|
|                  | Coef.                                   | SE      |
| 1993             | 0.083                                   | (0.125) |
| 1994             | −0.037                                  | (0.123) |
| 1995             | −0.052                                  | (0.122) |
| 1996             | −0.196                                  | (0.120) |
| 1997             | −0.039                                  | (0.119) |
| 1998 (reference) |                                         |         |
| 1999             | 0.037                                   | (0.118) |
| 2000             | 0.092                                   | (0.120) |
| 2001             | 0.140                                   | (0.121) |
| 2002             | 0.186                                   | (0.122) |
| 2003             | 0.353***                                | (0.124) |
| 2004             | 0.362***                                | (0.126) |
| 2005             | 0.441***                                | (0.128) |
| 2006             | 0.344***                                | (0.130) |
| 2007             | 0.426***                                | (0.131) |
| 2008             | 0.375***                                | (0.132) |
| 2009             | 0.379***                                | (0.134) |

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Table B.4 (continued).

|      | (1)<br>Probability to train apprentices |         |
|------|-----------------------------------------|---------|
|      | Coef.                                   | SE      |
| 2010 | 0.494***                                | (0.136) |
| 2011 | 0.386***                                | (0.138) |
| 2012 | 0.270*                                  | (0.140) |
| 2013 | 0.302**                                 | (0.142) |
| 2014 | 0.142                                   | (0.144) |
| 2015 | 0.350**                                 | (0.144) |
| 2016 | 0.247*                                  | (0.147) |
| 2017 | 0.220                                   | (0.149) |
| 2018 | 0.224                                   | (0.150) |
| Obs. | 213,204                                 |         |

Note: \*p < 0.1, \*\*p < 0.05, \*\*\*p < 0.01, coefficients of the interaction of firm location in BR with the years from an estimation according to Eq. (1) using a logit model, accounting for firm-fixed effects, weighted to adjust for disproportional selection of control regions.

Table B.5

Estimated reform effects on regions and firms in general.

Source: BeH 1993–2018.

|                  | (1)<br>Log apprentices<br>(region-level) |         | (2)<br>Log apprentice wage<br>(region-level) |         | (3)<br>Log apprentices<br>(stayer firms) |         | (4)<br>Log apprentice wage<br>(stayer firms) |         | (5)<br>Apprentice to<br>skilled worker ratio |         | (6)<br>Apprentice to 1998<br>firm size ratio |         |
|------------------|------------------------------------------|---------|----------------------------------------------|---------|------------------------------------------|---------|----------------------------------------------|---------|----------------------------------------------|---------|----------------------------------------------|---------|
|                  | Coef.                                    | SE      | Coef.                                        | SE      | Coef.                                    | SE      | Coef.                                        | SE      | Coef.                                        | SE      | Coef.                                        | SE      |
| 1993             | 0.085                                    | (0.054) | 0.006                                        | (0.025) | −0.059                                   | (0.067) | 0.027                                        | (0.021) | −0.014*                                      | (0.007) | 0.014                                        | (0.050) |
| 1994             | 0.130                                    | (0.090) | 0.013                                        | (0.030) | −0.011                                   | (0.068) | 0.004                                        | (0.021) | −0.010                                       | (0.007) | 0.008                                        | (0.045) |
| 1995             | 0.082                                    | (0.096) | 0.009                                        | (0.024) | −0.013                                   | (0.044) | 0.021                                        | (0.022) | −0.017***                                    | (0.006) | 0.003                                        | (0.043) |
| 1996             | 0.117                                    | (0.079) | 0.017                                        | (0.020) | 0.044                                    | (0.035) | 0.024*                                       | (0.013) | −0.014*                                      | (0.007) | −0.009                                       | (0.037) |
| 1997             | 0.098*                                   | (0.051) | 0.002                                        | (0.022) | 0.004                                    | (0.030) | 0.004                                        | (0.019) | −0.001                                       | (0.003) | 0.023                                        | (0.029) |
| 1998 (reference) |                                          |         |                                              |         |                                          |         |                                              |         |                                              |         |                                              |         |
| 1999             | 0.057                                    | (0.048) | −0.070***                                    | (0.016) | 0.007                                    | (0.031) | −0.005                                       | (0.017) | 0.010*                                       | (0.006) | 0.023                                        | (0.031) |
| 2000             | 0.017                                    | (0.076) | −0.073***                                    | (0.027) | 0.018                                    | (0.044) | −0.023                                       | (0.015) | 0.018**                                      | (0.008) | 0.014                                        | (0.034) |
| 2001             | 0.033                                    | (0.097) | −0.027                                       | (0.022) | 0.028                                    | (0.035) | 0.020                                        | (0.017) | 0.009                                        | (0.008) | 0.013                                        | (0.033) |
| 2002             | 0.101                                    | (0.099) | 0.013                                        | (0.017) | 0.018                                    | (0.041) | 0.041***                                     | (0.015) | 0.009                                        | (0.010) | 0.014                                        | (0.034) |
| 2003             | 0.248***                                 | (0.085) | −0.048*                                      | (0.024) | 0.075**                                  | (0.032) | 0.002                                        | (0.018) | 0.019*                                       | (0.010) | 0.024                                        | (0.034) |
| 2004             | 0.166                                    | (0.108) | −0.012                                       | (0.026) | 0.038*                                   | (0.022) | 0.002                                        | (0.018) | 0.001                                        | (0.009) | 0.018                                        | (0.035) |
| 2005             | 0.216**                                  | (0.105) | −0.057**                                     | (0.022) | 0.084**                                  | (0.032) | 0.010                                        | (0.015) | 0.020*                                       | (0.011) | 0.030                                        | (0.034) |
| 2006             | 0.252***                                 | (0.090) | −0.072***                                    | (0.027) | 0.044                                    | (0.033) | 0.002                                        | (0.012) | 0.022**                                      | (0.009) | 0.027                                        | (0.034) |
| 2007             | 0.266***                                 | (0.067) | −0.042*                                      | (0.022) | 0.069*                                   | (0.035) | 0.010                                        | (0.011) | 0.029***                                     | (0.011) | 0.033                                        | (0.033) |
| 2008             | 0.268***                                 | (0.078) | −0.044**                                     | (0.017) | 0.088**                                  | (0.039) | 0.014                                        | (0.014) | 0.028***                                     | (0.007) | 0.035                                        | (0.031) |
| 2009             | 0.220**                                  | (0.086) | −0.047**                                     | (0.021) | 0.109***                                 | (0.039) | −0.001                                       | (0.014) | 0.023***                                     | (0.008) | 0.034                                        | (0.032) |
| 2010             | 0.234**                                  | (0.108) | −0.030                                       | (0.022) | 0.123***                                 | (0.045) | 0.010                                        | (0.016) | 0.031***                                     | (0.009) | 0.039                                        | (0.032) |
| 2011             | 0.167                                    | (0.103) | −0.034                                       | (0.028) | 0.088**                                  | (0.040) | 0.003                                        | (0.020) | 0.027***                                     | (0.007) | 0.040                                        | (0.030) |
| 2012             | 0.194*                                   | (0.097) | −0.001                                       | (0.025) | 0.068                                    | (0.049) | 0.004                                        | (0.013) | 0.018*                                       | (0.010) | 0.038                                        | (0.030) |
| 2013             | 0.235**                                  | (0.102) | −0.014                                       | (0.030) | 0.101*                                   | (0.060) | 0.002                                        | (0.016) | 0.015                                        | (0.012) | 0.029                                        | (0.033) |
| 2014             | 0.267**                                  | (0.110) | −0.028                                       | (0.024) | 0.122**                                  | (0.046) | 0.005                                        | (0.016) | 0.018*                                       | (0.010) | 0.029                                        | (0.033) |
| 2015             | 0.297***                                 | (0.104) | −0.036                                       | (0.023) | 0.127***                                 | (0.047) | 0.012                                        | (0.017) | 0.021                                        | (0.014) | 0.037                                        | (0.030) |
| 2016             | 0.234**                                  | (0.095) | −0.023                                       | (0.024) | 0.137***                                 | (0.046) | 0.015                                        | (0.016) | 0.017                                        | (0.013) | 0.034                                        | (0.030) |
| 2017             | 0.243**                                  | (0.096) | −0.032                                       | (0.028) | 0.140**                                  | (0.061) | 0.012                                        | (0.018) | 0.013                                        | (0.012) | 0.031                                        | (0.030) |
| 2018             | 0.264*                                   | (0.142) | −0.060***                                    | (0.021) | 0.172**                                  | (0.078) | 0.014                                        | (0.019) | 0.022                                        | (0.016) | 0.042                                        | (0.031) |
| Obs.             | 14,913                                   |         | 14,913                                       |         | 64,458                                   |         | 64,458                                       |         | 380,096                                      |         | 402,539                                      |         |

Note: \*p < 0.1, \*\*p < 0.05, \*\*\*p < 0.01, coefficients of the interaction of firm location in BR with the years from an estimation according to Eq. (1), accounting for firm-fixed effects, weighted to adjust for disproportional selection of control regions. Standard errors in parentheses are clustered at the level of 62 municipal associations.

**Table B.6**

Estimated reform effects using different weights.

Source: BeH 1993–2018.

|                  | (1)<br>Log apprentices |         | (2)<br>Log apprentice wage |         | (3)<br>Log apprentices |         | (4)<br>Log apprentice wage |         |
|------------------|------------------------|---------|----------------------------|---------|------------------------|---------|----------------------------|---------|
|                  | Coef.                  | SE      | Coef.                      | SE      | Coef.                  | SE      | Coef.                      | SE      |
| 1993             | −0.020                 | (0.022) | 0.030**                    | (0.014) | −0.014                 | (0.038) | 0.034***                   | (0.011) |
| 1994             | −0.004                 | (0.031) | 0.010                      | (0.014) | 0.013                  | (0.045) | 0.002                      | (0.014) |
| 1995             | −0.028                 | (0.023) | 0.021                      | (0.015) | 0.014                  | (0.038) | 0.005                      | (0.014) |
| 1996             | 0.006                  | (0.021) | 0.008                      | (0.009) | 0.048                  | (0.031) | 0.001                      | (0.012) |
| 1997             | −0.006                 | (0.022) | 0.004                      | (0.009) | 0.021                  | (0.028) | 0.006                      | (0.011) |
| 1998 (reference) |                        |         |                            |         |                        |         |                            |         |
| 1999             | 0.013                  | (0.016) | −0.009                     | (0.011) | 0.012                  | (0.026) | −0.007                     | (0.013) |
| 2000             | 0.010                  | (0.019) | −0.017**                   | (0.008) | 0.021                  | (0.029) | −0.013*                    | (0.007) |
| 2001             | 0.023                  | (0.029) | 0.014                      | (0.009) | 0.039                  | (0.045) | 0.013                      | (0.009) |
| 2002             | 0.019                  | (0.014) | 0.034***                   | (0.011) | 0.048**                | (0.022) | 0.028***                   | (0.008) |
| 2003             | 0.066**                | (0.027) | −0.015                     | (0.010) | 0.100**                | (0.043) | −0.015                     | (0.015) |
| 2004             | 0.010                  | (0.023) | 0.002                      | (0.011) | 0.036                  | (0.046) | 0.005                      | (0.016) |
| 2005             | 0.053                  | (0.036) | 0.005                      | (0.007) | 0.057                  | (0.067) | 0.004                      | (0.011) |
| 2006             | 0.044                  | (0.040) | −0.001                     | (0.006) | 0.007                  | (0.070) | −0.001                     | (0.010) |
| 2007             | 0.059*                 | (0.030) | 0.002                      | (0.007) | 0.034                  | (0.058) | 0.001                      | (0.014) |
| 2008             | 0.081***               | (0.023) | 0.011                      | (0.007) | 0.089*                 | (0.049) | 0.003                      | (0.012) |
| 2009             | 0.047*                 | (0.028) | 0.001                      | (0.010) | 0.038                  | (0.054) | −0.002                     | (0.012) |
| 2010             | 0.069*                 | (0.036) | 0.007                      | (0.009) | 0.098                  | (0.065) | 0.000                      | (0.012) |
| 2011             | 0.050*                 | (0.030) | 0.006                      | (0.012) | 0.058                  | (0.061) | 0.008                      | (0.012) |
| 2012             | 0.059**                | (0.027) | 0.004                      | (0.010) | 0.060                  | (0.060) | 0.006                      | (0.012) |
| 2013             | 0.098***               | (0.027) | 0.012                      | (0.013) | 0.115***               | (0.043) | 0.009                      | (0.015) |
| 2014             | 0.100***               | (0.025) | 0.009                      | (0.012) | 0.099**                | (0.042) | 0.007                      | (0.012) |
| 2015             | 0.104***               | (0.028) | 0.009                      | (0.011) | 0.105**                | (0.050) | 0.004                      | (0.011) |
| 2016             | 0.156***               | (0.031) | 0.023**                    | (0.011) | 0.132*                 | (0.069) | 0.019*                     | (0.011) |
| 2017             | 0.133***               | (0.041) | 0.020                      | (0.013) | 0.095*                 | (0.055) | 0.009                      | (0.018) |
| 2018             | 0.147***               | (0.054) | 0.022                      | (0.017) | 0.135*                 | (0.070) | 0.003                      | (0.014) |
| Obs.             | 123,512                |         | 123,512                    |         | 111,704                |         | 111,704                    |         |
| Weight           | Population size 1998   |         | Population size 1998       |         | Firm size 1998         |         | Firm size 1998             |         |

Note: \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ , coefficients of the interaction of firm location in BR with the years from an estimation according to Eq. (1), accounting for firm-fixed effects, weighted to adjust for disproportional selection of control regions. Standard errors in parentheses are clustered at the level of 62 municipal associations.

**Table B.7**

Results using travel time to the next Swiss city as a continuous treatment measure.

Source: BeH 1993–2018.

|                                     | (1)<br>Number of<br>apprentices | (2)<br>Apprentice<br>wage |
|-------------------------------------|---------------------------------|---------------------------|
| <i>Transition</i> × log travel time | −0.008**<br>(0.004)             | 0.004**<br>(0.001)        |
| <i>Free</i> × log travel time       | −0.031***<br>(0.003)            | −0.001<br>(0.001)         |
| Observations                        | 123,512                         | 123,512                   |

Note: \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ , coefficients of the interaction of location of firm in log travel time with Transition and Free Movement Phase indicators, accounting for firm-fixed effects, weighted to adjust for disproportional selection of control regions. Standard errors in parentheses are clustered at the level of 62 municipal associations.

**Table B.8**

Estimated reform effects considering the other AFMP regions located farther away than 30 min from the border.

Source: BeH 1993–2018.

|                  | (1)<br>Log apprentices<br>other AFMP (Travel time > 30 min.)<br>Reference matched control regions |         | (2)<br>Log apprentice wage<br>other AFMP (Travel time > 30 min.)<br>Reference matched control regions |         | (3)<br>Log apprentices<br>BR (Travel time ≤ 30 min.)<br>Reference other AFMP regions |         | (4)<br>Log apprentice wage<br>BR (Travel time ≤ 30 min.)<br>Reference other AFMP regions |         |
|------------------|---------------------------------------------------------------------------------------------------|---------|-------------------------------------------------------------------------------------------------------|---------|--------------------------------------------------------------------------------------|---------|------------------------------------------------------------------------------------------|---------|
|                  | Coef.                                                                                             | SE      | Coef.                                                                                                 | SE      | Coef.                                                                                | SE      | Coef.                                                                                    | SE      |
|                  |                                                                                                   |         |                                                                                                       |         |                                                                                      |         |                                                                                          |         |
| 1993             | −0.052***                                                                                         | (0.020) | 0.021                                                                                                 | (0.013) | 0.027                                                                                | (0.022) | 0.012                                                                                    | (0.011) |
| 1994             | −0.045**                                                                                          | (0.018) | 0.017*                                                                                                | (0.009) | 0.037                                                                                | (0.033) | −0.009                                                                                   | (0.014) |
| 1995             | −0.037**                                                                                          | (0.016) | 0.014                                                                                                 | (0.009) | 0.012                                                                                | (0.024) | 0.009                                                                                    | (0.015) |
| 1996             | −0.024*                                                                                           | (0.013) | 0.003                                                                                                 | (0.009) | 0.033                                                                                | (0.021) | 0.005                                                                                    | (0.011) |
| 1997             | −0.014                                                                                            | (0.011) | −0.009                                                                                                | (0.009) | 0.010                                                                                | (0.022) | 0.015                                                                                    | (0.010) |
| 1998 (reference) |                                                                                                   |         |                                                                                                       |         |                                                                                      |         |                                                                                          |         |
| 1999             | −0.016                                                                                            | (0.011) | −0.006                                                                                                | (0.006) | 0.027                                                                                | (0.017) | −0.001                                                                                   | (0.010) |
| 2000             | −0.051***                                                                                         | (0.012) | −0.005                                                                                                | (0.008) | 0.061***                                                                             | (0.019) | −0.010                                                                                   | (0.007) |
| 2001             | −0.026*                                                                                           | (0.014) | 0.006                                                                                                 | (0.007) | 0.051*                                                                               | (0.030) | 0.008                                                                                    | (0.011) |
| 2002             | −0.013                                                                                            | (0.015) | 0.006                                                                                                 | (0.005) | 0.035**                                                                              | (0.017) | 0.028**                                                                                  | (0.011) |
| 2003             | 0.018                                                                                             | (0.015) | −0.007                                                                                                | (0.008) | 0.051*                                                                               | (0.025) | −0.009                                                                                   | (0.010) |
| 2004             | 0.005                                                                                             | (0.023) | −0.005                                                                                                | (0.008) | 0.007                                                                                | (0.024) | 0.005                                                                                    | (0.010) |
| 2005             | 0.035*                                                                                            | (0.019) | 0.003                                                                                                 | (0.005) | 0.026                                                                                | (0.036) | −0.000                                                                                   | (0.008) |
| 2006             | 0.033                                                                                             | (0.021) | 0.012*                                                                                                | (0.007) | 0.019                                                                                | (0.042) | −0.016**                                                                                 | (0.008) |
| 2007             | 0.028                                                                                             | (0.020) | 0.010                                                                                                 | (0.007) | 0.037                                                                                | (0.028) | −0.010                                                                                   | (0.008) |
| 2008             | 0.056***                                                                                          | (0.021) | 0.010                                                                                                 | (0.008) | 0.032                                                                                | (0.025) | −0.002                                                                                   | (0.009) |
| 2009             | 0.045*                                                                                            | (0.025) | 0.004                                                                                                 | (0.009) | 0.012                                                                                | (0.030) | −0.006                                                                                   | (0.012) |
| 2010             | 0.054*                                                                                            | (0.028) | 0.008                                                                                                 | (0.009) | 0.027                                                                                | (0.038) | −0.004                                                                                   | (0.010) |
| 2011             | 0.026                                                                                             | (0.025) | 0.019**                                                                                               | (0.009) | 0.033                                                                                | (0.035) | −0.013                                                                                   | (0.013) |
| 2012             | 0.016                                                                                             | (0.026) | 0.017*                                                                                                | (0.010) | 0.049                                                                                | (0.032) | −0.014                                                                                   | (0.009) |
| 2013             | 0.042                                                                                             | (0.029) | 0.015                                                                                                 | (0.010) | 0.061**                                                                              | (0.029) | −0.005                                                                                   | (0.013) |
| 2014             | 0.030                                                                                             | (0.025) | 0.021*                                                                                                | (0.011) | 0.077***                                                                             | (0.027) | −0.013                                                                                   | (0.013) |
| 2015             | 0.023                                                                                             | (0.033) | 0.012                                                                                                 | (0.012) | 0.087**                                                                              | (0.033) | −0.007                                                                                   | (0.011) |
| 2016             | 0.064**                                                                                           | (0.030) | 0.017                                                                                                 | (0.011) | 0.098***                                                                             | (0.034) | −0.000                                                                                   | (0.011) |
| 2017             | 0.051*                                                                                            | (0.026) | 0.017                                                                                                 | (0.011) | 0.084*                                                                               | (0.045) | −0.000                                                                                   | (0.012) |
| 2018             | 0.068**                                                                                           | (0.031) | 0.014                                                                                                 | (0.011) | 0.084                                                                                | (0.054) | 0.003                                                                                    | (0.014) |
| Obs.             |                                                                                                   | 143,636 |                                                                                                       | 143,636 |                                                                                      | 65,659  |                                                                                          | 65,659  |

Note: \*p < 0.1, \*\*p < 0.05, \*\*\*p < 0.01, coefficients of the interaction of firm location in BR with the years from an estimation according to Eq. (1), accounting for firm-fixed effects, weighted to adjust for disproportional selection of control regions. Columns 1 and 2 compares firms in other AFMP regions that are located farther away than 30 min travel time to firms in the matched control regions; Columns 3 and 4 compares BR firms, located within 30 min from the next Swiss city, to firms in other AFMP regions located farther away. Standard errors in parentheses are clustered at the level of 62 municipal associations.

**Table B.9**

Estimated reform effects without sectors heavily affected by the trade agreement MRA.

Source: BeH 1993–2018.

|                  | (1)<br>Log apprentices |         | (2)<br>Log apprentice wage |         | (3)<br>Log skilled workers |         |
|------------------|------------------------|---------|----------------------------|---------|----------------------------|---------|
|                  | Coef.                  | SE      | Coef.                      | SE      | Coef.                      | SE      |
| 1993             | 0.010                  | (0.030) | 0.035**                    | (0.015) | 0.036                      | (0.025) |
| 1994             | 0.011                  | (0.040) | 0.008                      | (0.016) | 0.028                      | (0.019) |
| 1995             | −0.027                 | (0.033) | 0.023                      | (0.017) | 0.022                      | (0.020) |
| 1996             | 0.041                  | (0.028) | 0.004                      | (0.014) | −0.002                     | (0.018) |
| 1997             | 0.000                  | (0.026) | 0.003                      | (0.012) | −0.002                     | (0.005) |
| 1998 (reference) |                        |         |                            |         |                            |         |
| 1999             | −0.005                 | (0.019) | −0.012                     | (0.012) | −0.010                     | (0.010) |
| 2000             | −0.007                 | (0.030) | −0.024*                    | (0.012) | −0.009                     | (0.014) |
| 2001             | 0.005                  | (0.027) | 0.010                      | (0.011) | −0.002                     | (0.015) |
| 2002             | 0.018                  | (0.022) | 0.030**                    | (0.014) | −0.006                     | (0.014) |
| 2003             | 0.079***               | (0.027) | −0.017                     | (0.012) | 0.004                      | (0.012) |
| 2004             | 0.018                  | (0.024) | 0.002                      | (0.013) | 0.018                      | (0.015) |
| 2005             | 0.079**                | (0.031) | −0.004                     | (0.010) | 0.024*                     | (0.014) |
| 2006             | 0.080***               | (0.027) | −0.002                     | (0.009) | 0.037**                    | (0.016) |
| 2007             | 0.088**                | (0.036) | −0.002                     | (0.008) | 0.044*                     | (0.022) |
| 2008             | 0.119***               | (0.034) | −0.000                     | (0.010) | 0.018                      | (0.016) |
| 2009             | 0.062*                 | (0.034) | −0.008                     | (0.012) | 0.015                      | (0.017) |
| 2010             | 0.099**                | (0.045) | 0.004                      | (0.011) | 0.010                      | (0.024) |
| 2011             | 0.051                  | (0.046) | −0.006                     | (0.014) | 0.018                      | (0.020) |
| 2012             | 0.061                  | (0.037) | −0.002                     | (0.012) | 0.030                      | (0.023) |
| 2013             | 0.092**                | (0.037) | 0.008                      | (0.016) | 0.038*                     | (0.020) |
| 2014             | 0.104***               | (0.024) | 0.002                      | (0.018) | 0.047**                    | (0.023) |

(continued on next page)

**Table B.9** (continued).

|      | (1)<br>Log apprentices |         | (2)<br>Log apprentice wage |         | (3)<br>Log skilled workers |         |
|------|------------------------|---------|----------------------------|---------|----------------------------|---------|
|      | Coef.                  | SE      | Coef.                      | SE      | Coef.                      | SE      |
| 2015 | 0.123***               | (0.027) | 0.002                      | (0.014) | 0.056**                    | (0.022) |
| 2016 | 0.154***               | (0.029) | 0.017                      | (0.016) | 0.057**                    | (0.026) |
| 2017 | 0.134***               | (0.039) | 0.003                      | (0.017) | 0.041                      | (0.029) |
| 2018 | 0.159***               | (0.058) | 0.020                      | (0.017) | 0.033                      | (0.030) |
| Obs. | 93,349                 |         | 93,349                     |         | 287,779                    |         |

Note: \*p < 0.1, \*\*p < 0.05, \*\*\*p < 0.01, coefficients of the interaction of firm location in BR with the years from an estimation according to Eq. (1), accounting for firm-fixed effects, weighted to adjust for disproportional selection of control regions. Sample excludes sectors that were heavily affected by the MRA: manufacturing of furniture, manufacturing of other goods (jewelry, toys, etc.), wholesale, retail, and sale of motor vehicles (Bühler et al., 2013). Standard errors in parentheses are clustered at the level of 62 municipal associations.

**Table B.10**

Estimated reform effects accounting for the concurrent G8 school reform.

Source: BeH 1993–2018, Data on school leavers were retrieved from the INKAR database by the Federal Institute for Research on Building, Urban Affairs and Spatial Development.

|                  | (1)<br>Log apprentices |         | (2)<br>Log apprentice wage |         | (3)<br>Log apprentices |         | (4)<br>Log apprentice wage |         |
|------------------|------------------------|---------|----------------------------|---------|------------------------|---------|----------------------------|---------|
|                  | Coef.                  | SE      | Coef.                      | SE      | Coef.                  | SE      |                            |         |
| 1993             |                        |         |                            |         | −0.023                 | (0.022) | 0.031**                    | (0.014) |
| 1994             |                        |         |                            |         | −0.008                 | (0.031) | 0.009                      | (0.014) |
| 1995             | −0.005                 | (0.027) | 0.027*                     | (0.016) | −0.026                 | (0.025) | 0.022                      | (0.015) |
| 1996             | 0.011                  | (0.025) | 0.015                      | (0.010) | 0.009                  | (0.022) | 0.010                      | (0.011) |
| 1997             | −0.000                 | (0.023) | 0.009                      | (0.010) | −0.005                 | (0.022) | 0.006                      | (0.009) |
| 1998 (reference) |                        |         |                            |         |                        |         |                            |         |
| 1999             | 0.012                  | (0.016) | −0.007                     | (0.011) | 0.012                  | (0.016) | −0.009                     | (0.010) |
| 2000             | 0.007                  | (0.020) | −0.017**                   | (0.008) | 0.010                  | (0.020) | −0.018**                   | (0.008) |
| 2001             | 0.021                  | (0.028) | 0.017*                     | (0.010) | 0.024                  | (0.030) | 0.015                      | (0.010) |
| 2002             | 0.019                  | (0.016) | 0.037***                   | (0.011) | 0.021                  | (0.016) | 0.034***                   | (0.011) |
| 2003             | 0.070***               | (0.026) | −0.013                     | (0.011) | 0.069**                | (0.027) | −0.015                     | (0.010) |
| 2004             | 0.026                  | (0.020) | 0.004                      | (0.011) | 0.012                  | (0.024) | 0.002                      | (0.010) |
| 2005             | 0.068**                | (0.033) | 0.006                      | (0.008) | 0.060                  | (0.037) | 0.004                      | (0.008) |
| 2006             | 0.053                  | (0.038) | 0.000                      | (0.007) | 0.049                  | (0.040) | −0.002                     | (0.007) |
| 2007             | 0.067**                | (0.027) | 0.003                      | (0.009) | 0.065**                | (0.030) | 0.002                      | (0.007) |
| 2008             | 0.084***               | (0.025) | 0.011                      | (0.008) | 0.087***               | (0.026) | 0.011                      | (0.008) |
| 2009             | 0.056*                 | (0.029) | 0.002                      | (0.010) | 0.056*                 | (0.030) | 0.002                      | (0.010) |
| 2010             | 0.081**                | (0.039) | 0.008                      | (0.009) | 0.076*                 | (0.040) | 0.006                      | (0.009) |
| 2011             | 0.056                  | (0.034) | 0.008                      | (0.013) | 0.053                  | (0.035) | 0.006                      | (0.013) |
| 2012             | 0.065**                | (0.030) | 0.006                      | (0.010) | 0.080***               | (0.030) | 0.009                      | (0.011) |
| 2013             | 0.121***               | (0.029) | 0.013                      | (0.013) | 0.093***               | (0.029) | 0.008                      | (0.013) |
| 2014             | 0.116***               | (0.025) | 0.011                      | (0.012) | 0.106***               | (0.027) | 0.009                      | (0.012) |
| 2015             | 0.119***               | (0.030) | 0.014                      | (0.010) | 0.111***               | (0.030) | 0.009                      | (0.010) |
| 2016             | 0.171***               | (0.033) | 0.028***                   | (0.009) | 0.162***               | (0.033) | 0.020*                     | (0.011) |
| 2017             | 0.140***               | (0.045) | 0.025**                    | (0.011) | 0.142***               | (0.044) | 0.018                      | (0.013) |
| 2018             | 0.159***               | (0.058) | 0.028*                     | (0.015) | 0.157***               | (0.056) | 0.020                      | (0.016) |
| Control          | Log school leavers     |         | Log school leavers         |         | School reform dummy    |         | School reform dummy        |         |
| Obs.             | 105,864                |         | 105,864                    |         | 123,512                |         | 123,512                    |         |

Note: \*p < 0.1, \*\*p < 0.05, \*\*\*p < 0.01, coefficients of the interaction of firm location in BR with the years from an estimation according to Eq. (1), accounting for firm-fixed effects, weighted to adjust for disproportional selection of control regions. Standard errors in parentheses are clustered at the level of 62 municipal associations.

**Table B.11**

Estimated reform effects on log apprentices by firm characteristics.

Source: BeH 1993–2018.

|                  | (1)<br>Firm size ≤ 10 |         | (2)<br>Firm size > 10 |         | (3)<br>Industry |         | (4)<br>Services |         | (5)<br>Above ave. skilled<br>workers share |         | (6)<br>Below ave. skilled<br>worker share |         |
|------------------|-----------------------|---------|-----------------------|---------|-----------------|---------|-----------------|---------|--------------------------------------------|---------|-------------------------------------------|---------|
|                  | Coef.                 | SE      | Coef.                 | SE      | Coef.           | SE      | Coef.           | SE      | Coef.                                      | SE      | Coef.                                     | SE      |
| 1993             | −0.013                | (0.020) | −0.038                | (0.052) | 0.013           | (0.041) | −0.044          | (0.036) | −0.024                                     | (0.022) | −0.021                                    | (0.051) |
| 1994             | −0.022                | (0.023) | 0.013                 | (0.058) | −0.009          | (0.033) | −0.005          | (0.045) | −0.013                                     | (0.022) | 0.007                                     | (0.066) |
| 1995             | −0.049                | (0.032) | 0.006                 | (0.048) | −0.051          | (0.041) | −0.011          | (0.028) | −0.018                                     | (0.025) | −0.042                                    | (0.039) |
| 1996             | −0.021                | (0.029) | 0.052                 | (0.039) | 0.027           | (0.036) | −0.002          | (0.031) | 0.028                                      | (0.019) | −0.027                                    | (0.038) |
| 1997             | −0.014                | (0.024) | 0.008                 | (0.036) | −0.021          | (0.031) | 0.005           | (0.027) | −0.016                                     | (0.029) | 0.014                                     | (0.037) |
| 1998 (reference) |                       |         |                       |         |                 |         |                 |         |                                            |         |                                           |         |
| 1999             | 0.024                 | (0.017) | −0.007                | (0.047) | −0.046*         | (0.024) | 0.048***        | (0.017) | 0.005                                      | (0.026) | 0.024                                     | (0.023) |
| 2000             | −0.008                | (0.016) | 0.036                 | (0.044) | −0.065          | (0.052) | 0.056***        | (0.018) | 0.006                                      | (0.024) | 0.013                                     | (0.033) |
| 2001             | −0.000                | (0.021) | 0.059                 | (0.056) | −0.004          | (0.056) | 0.045           | (0.040) | 0.017                                      | (0.029) | 0.038                                     | (0.047) |
| 2002             | −0.044                | (0.029) | 0.121***              | (0.026) | 0.006           | (0.032) | 0.034           | (0.027) | 0.005                                      | (0.018) | 0.047                                     | (0.046) |
| 2003             | 0.015                 | (0.027) | 0.145**               | (0.057) | 0.046           | (0.053) | 0.089           | (0.055) | 0.081**                                    | (0.037) | 0.041                                     | (0.045) |
| 2004             | −0.033                | (0.023) | 0.071                 | (0.054) | −0.012          | (0.037) | 0.032           | (0.049) | 0.030                                      | (0.037) | −0.026                                    | (0.059) |
| 2005             | 0.034*                | (0.019) | 0.094                 | (0.072) | 0.024           | (0.044) | 0.086           | (0.074) | 0.091**                                    | (0.045) | −0.002                                    | (0.059) |
| 2006             | 0.075**               | (0.030) | 0.017                 | (0.076) | 0.045           | (0.060) | 0.056           | (0.090) | 0.100**                                    | (0.041) | −0.051                                    | (0.076) |
| 2007             | 0.088***              | (0.031) | 0.038                 | (0.057) | 0.071           | (0.059) | 0.066           | (0.072) | 0.111***                                   | (0.037) | −0.031                                    | (0.036) |
| 2008             | 0.077**               | (0.033) | 0.107**               | (0.051) | 0.121           | (0.083) | 0.070           | (0.059) | 0.109***                                   | (0.036) | 0.040                                     | (0.061) |
| 2009             | 0.057                 | (0.037) | 0.058                 | (0.062) | 0.027           | (0.076) | 0.077           | (0.073) | 0.079**                                    | (0.037) | 0.006                                     | (0.046) |
| 2010             | 0.057                 | (0.038) | 0.107                 | (0.073) | 0.062           | (0.067) | 0.092           | (0.077) | 0.081                                      | (0.055) | 0.072                                     | (0.053) |
| 2011             | 0.053*                | (0.027) | 0.065                 | (0.068) | 0.042           | (0.059) | 0.070           | (0.049) | 0.045                                      | (0.053) | 0.077                                     | (0.062) |
| 2012             | 0.045                 | (0.037) | 0.095                 | (0.066) | 0.060           | (0.075) | 0.072           | (0.058) | 0.085**                                    | (0.035) | 0.020                                     | (0.064) |
| 2013             | 0.069*                | (0.038) | 0.149**               | (0.060) | 0.106           | (0.083) | 0.104**         | (0.043) | 0.110***                                   | (0.037) | 0.083                                     | (0.069) |
| 2014             | 0.101**               | (0.045) | 0.119**               | (0.046) | 0.122           | (0.084) | 0.095           | (0.072) | 0.115***                                   | (0.035) | 0.086*                                    | (0.048) |
| 2015             | 0.087*                | (0.047) | 0.142**               | (0.055) | 0.080           | (0.057) | 0.137***        | (0.049) | 0.118***                                   | (0.038) | 0.092                                     | (0.060) |
| 2016             | 0.153***              | (0.053) | 0.184**               | (0.080) | 0.136*          | (0.070) | 0.188***        | (0.056) | 0.199***                                   | (0.046) | 0.092                                     | (0.061) |
| 2017             | 0.183***              | (0.063) | 0.112                 | (0.071) | 0.091           | (0.090) | 0.180***        | (0.048) | 0.161**                                    | (0.063) | 0.096                                     | (0.067) |
| 2018             | 0.166**               | (0.079) | 0.158*                | (0.087) | 0.117           | (0.098) | 0.190***        | (0.047) | 0.170**                                    | (0.067) | 0.126*                                    | (0.075) |
| Obs.             | 70,012                |         | 53,500                |         | 46,858          |         | 76,654          |         | 83,007                                     |         | 40,505                                    |         |

Note: \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ , coefficients of the interaction of firm location in BR with the years from an estimation according to Eq. (1), accounting for firm-fixed effects, weighted to adjust for disproportional selection of control regions. Column 1 and 2 selects firms according to their firm size in 1998, Column 3 and 4 separates firms in Agriculture, Energy, Manufacturing, and Construction (Industry) from all other sectors (Services), Column 5 and 6 distinguishes firms by below and above average skilled worker share in 1998. Standard errors in parentheses are clustered at the level of 62 municipal associations.

**Table B.12**

Estimated reform effects on log apprentice wages by firm characteristics.

Source: BeH 1993–2018.

|                  | (1)<br>Firm size ≤ 10 |         | (2)<br>Firm size > 10 |         | (3)<br>Industry |         | (4)<br>Services |         | (5)<br>Above ave. skilled<br>workers share |         | (6)<br>Below ave. skilled<br>worker share |         |
|------------------|-----------------------|---------|-----------------------|---------|-----------------|---------|-----------------|---------|--------------------------------------------|---------|-------------------------------------------|---------|
|                  | Coef.                 | SE      | Coef.                 | SE      | Coef.           | SE      | Coef.           | SE      | Coef.                                      | SE      | Coef.                                     | SE      |
| 1993             | 0.011                 | (0.021) | 0.060***              | (0.014) | 0.005           | (0.021) | 0.045***        | (0.016) | 0.026                                      | (0.017) | 0.039                                     | (0.025) |
| 1994             | −0.003                | (0.014) | 0.028                 | (0.019) | 0.011           | (0.013) | 0.006           | (0.017) | 0.021                                      | (0.020) | −0.015                                    | (0.021) |
| 1995             | 0.042*                | (0.022) | −0.008                | (0.016) | 0.003           | (0.021) | 0.033*          | (0.018) | 0.021                                      | (0.020) | 0.023                                     | (0.019) |
| 1996             | 0.016                 | (0.013) | 0.001                 | (0.012) | −0.015          | (0.022) | 0.025**         | (0.011) | 0.008                                      | (0.012) | 0.011                                     | (0.021) |
| 1997             | 0.007                 | (0.012) | 0.005                 | (0.016) | −0.010          | (0.020) | 0.015           | (0.013) | −0.007                                     | (0.015) | 0.030                                     | (0.022) |
| 1998 (reference) |                       |         |                       |         |                 |         |                 |         |                                            |         |                                           |         |
| 1999             | −0.020**              | (0.009) | 0.007                 | (0.019) | −0.024          | (0.019) | 0.000           | (0.010) | −0.006                                     | (0.013) | −0.015                                    | (0.020) |
| 2000             | −0.031***             | (0.009) | 0.003                 | (0.011) | −0.051*         | (0.029) | 0.002           | (0.013) | −0.019**                                   | (0.009) | −0.013                                    | (0.026) |
| 2001             | 0.011                 | (0.014) | 0.022**               | (0.009) | −0.006          | (0.020) | 0.028           | (0.017) | 0.020                                      | (0.015) | 0.005                                     | (0.018) |
| 2002             | 0.042***              | (0.015) | 0.020*                | (0.011) | 0.013           | (0.026) | 0.045***        | (0.009) | 0.036**                                    | (0.017) | 0.030                                     | (0.026) |
| 2003             | −0.017*               | (0.009) | −0.012                | (0.019) | −0.023          | (0.022) | −0.011          | (0.012) | −0.016*                                    | (0.009) | −0.014                                    | (0.029) |
| 2004             | −0.011                | (0.010) | 0.019                 | (0.019) | 0.004           | (0.027) | 0.000           | (0.015) | 0.010*                                     | (0.005) | −0.015                                    | (0.033) |
| 2005             | −0.002                | (0.011) | 0.012                 | (0.011) | −0.011          | (0.026) | 0.013           | (0.012) | 0.011                                      | (0.010) | −0.010                                    | (0.023) |
| 2006             | −0.011                | (0.008) | 0.009                 | (0.011) | −0.024          | (0.019) | 0.010           | (0.012) | −0.001                                     | (0.009) | −0.005                                    | (0.018) |
| 2007             | −0.010                | (0.008) | 0.017                 | (0.014) | −0.016          | (0.017) | 0.012           | (0.012) | 0.009                                      | (0.009) | −0.014                                    | (0.021) |
| 2008             | 0.009                 | (0.012) | 0.014                 | (0.015) | 0.002           | (0.022) | 0.015           | (0.011) | 0.019                                      | (0.014) | −0.007                                    | (0.024) |
| 2009             | 0.001                 | (0.012) | 0.004                 | (0.013) | −0.017          | (0.024) | 0.012           | (0.012) | 0.009                                      | (0.011) | −0.014                                    | (0.024) |
| 2010             | 0.011                 | (0.011) | 0.003                 | (0.015) | −0.011          | (0.024) | 0.016*          | (0.009) | 0.011                                      | (0.010) | −0.003                                    | (0.020) |
| 2011             | −0.003                | (0.019) | 0.017                 | (0.013) | −0.012          | (0.026) | 0.018           | (0.017) | 0.013                                      | (0.014) | −0.008                                    | (0.024) |

(continued on next page)

Table B.12 (continued).

|      | (1)<br>Firm size $\leq 10$ |         | (2)<br>Firm size $> 10$ |         | (3)<br>Industry |         | (4)<br>Services |         | (5)<br>Above ave. skilled<br>workers share |         | (6)<br>Below ave. skilled<br>worker share |         |
|------|----------------------------|---------|-------------------------|---------|-----------------|---------|-----------------|---------|--------------------------------------------|---------|-------------------------------------------|---------|
|      | Coef.                      | SE      | Coef.                   | SE      | Coef.           | SE      | Coef.           | SE      | Coef.                                      | SE      | Coef.                                     | SE      |
| 2012 | −0.007                     | (0.018) | 0.018                   | (0.015) | −0.000          | (0.020) | 0.006           | (0.014) | 0.013                                      | (0.013) | −0.014                                    | (0.022) |
| 2013 | 0.009                      | (0.011) | 0.013                   | (0.018) | −0.005          | (0.025) | 0.021           | (0.015) | 0.012                                      | (0.011) | 0.008                                     | (0.031) |
| 2014 | 0.007                      | (0.015) | 0.012                   | (0.016) | 0.013           | (0.028) | 0.004           | (0.012) | 0.019                                      | (0.012) | −0.011                                    | (0.038) |
| 2015 | 0.002                      | (0.014) | 0.016                   | (0.015) | 0.021           | (0.023) | −0.001          | (0.010) | 0.020*                                     | (0.012) | −0.015                                    | (0.023) |
| 2016 | 0.001                      | (0.012) | 0.040**                 | (0.017) | 0.038           | (0.030) | 0.008           | (0.011) | 0.019                                      | (0.012) | 0.023                                     | (0.017) |
| 2017 | 0.009                      | (0.016) | 0.028                   | (0.022) | 0.022           | (0.035) | 0.013           | (0.022) | 0.019                                      | (0.014) | 0.014                                     | (0.030) |
| 2018 | 0.024                      | (0.021) | 0.014                   | (0.020) | 0.031           | (0.042) | 0.012           | (0.017) | 0.036                                      | (0.024) | −0.010                                    | (0.017) |
| Obs. | 70,012                     |         | 53,500                  |         | 46,858          |         | 76,654          |         | 83,007                                     |         | 40,505                                    |         |

Note: \*p < 0.1, \*\*p < 0.05, \*\*\*p < 0.01, coefficients of the interaction of firm location in BR with the years from an estimation according to Eq. (1), accounting for firm-fixed effects, weighted to adjust for disproportional selection of control regions. Column 1 and 2 selects firms according to their firm size in 1998, Column 3 and 4 separates firms in Agriculture, Energy, Manufacturing, and Construction (Industry) from all other sectors (Services), Column 5 and 6 distinguishes firms by below and above average skilled worker share in 1998. Standard errors in parentheses are clustered at the level of 62 municipal associations.

Table B.13

Estimated reform effects on log apprentice wages accounting for occupation and apprenticeship duration.

Source: BeH 1993–2018.

|                  | (1)<br>Log apprentices wages<br>of all apprentices |         | (2)<br>Log apprentice wages<br>of new apprentices |         |
|------------------|----------------------------------------------------|---------|---------------------------------------------------|---------|
|                  | Coef.                                              | SE      | Coef.                                             | SE      |
| 1993             | 0.029**                                            | (0.014) | 0.036                                             | (0.015) |
| 1994             | 0.009                                              | (0.014) | 0.006                                             | (0.011) |
| 1995             | 0.022                                              | (0.015) | 0.026                                             | (0.016) |
| 1996             | 0.011                                              | (0.010) | 0.017                                             | (0.008) |
| 1997             | 0.003                                              | (0.009) | 0.009                                             | (0.010) |
| 1998 (reference) |                                                    |         |                                                   |         |
| 1999             | −0.010                                             | (0.010) | −0.010                                            | (0.011) |
| 2000             | −0.018**                                           | (0.008) | −0.010                                            | (0.006) |
| 2001             | 0.015                                              | (0.010) | 0.018                                             | (0.008) |
| 2002             | 0.033***                                           | (0.010) | 0.044                                             | (0.010) |
| 2003             | −0.014                                             | (0.010) | −0.006                                            | (0.012) |
| 2004             | 0.002                                              | (0.011) | 0.017                                             | (0.015) |
| 2005             | 0.001                                              | (0.008) | −0.004                                            | (0.010) |
| 2006             | −0.004                                             | (0.008) | −0.002                                            | (0.010) |
| 2007             | 0.001                                              | (0.008) | 0.000                                             | (0.011) |
| 2008             | 0.006                                              | (0.008) | 0.003                                             | (0.010) |
| 2009             | −0.001                                             | (0.010) | 0.009                                             | (0.010) |
| 2010             | 0.003                                              | (0.009) | 0.007                                             | (0.009) |
| 2011             | −0.003                                             | (0.010) | 0.014                                             | (0.011) |
| 2012             | 0.002                                              | (0.010) | 0.011                                             | (0.012) |
| 2013             | 0.010                                              | (0.013) | 0.012                                             | (0.014) |
| 2014             | 0.007                                              | (0.013) | 0.023                                             | (0.014) |
| 2015             | 0.008                                              | (0.010) | 0.022                                             | (0.012) |
| 2016             | 0.020*                                             | (0.010) | 0.022                                             | (0.012) |
| 2017             | 0.017                                              | (0.013) | 0.018                                             | (0.014) |
| 2018             | 0.018                                              | (0.016) | 0.026                                             | (0.013) |
| Controls         | Occupation                                         |         |                                                   |         |
| Obs.             | 119,976                                            |         | 101,936                                           |         |

Note: \*p < 0.1, \*\*p < 0.05, \*\*\*p < 0.01, coefficients of the interaction of firm location in BR with the years from an estimation according to Eq. (1), accounting for firm-fixed effects, weighted to adjust for disproportional selection of control regions. Column 1 additionally controls for firm occupational composition at the 1-digit occupational groups of the German Occupational Classification (KldB 2010). Standard errors in parentheses are clustered at the level of 62 municipal associations.

**Table B.14**

Occupational composition of apprenticeships in the BR by reform phase.

Source: BeH 1993–2018 for Columns 1–3, SIAB 1996–1998 for Column 4.

| Occupational field                                                                                      | (1)<br>Pre-policy<br>1993–1998 | (2)<br>Transition<br>1999–2003 | (3)<br>Free<br>2004–2018 | (4)<br>Mean wage<br>1996–1998 |
|---------------------------------------------------------------------------------------------------------|--------------------------------|--------------------------------|--------------------------|-------------------------------|
| Agriculture, forestry,<br>farming, and gardening                                                        | 0.018                          | 0.013                          | 0.013                    | 21.85<br>(9.79)               |
| Production of raw<br>materials and goods,<br>and manufacturing                                          | 0.297                          | 0.300                          | 0.318                    | 25.77<br>(7.84)               |
| Construction, architecture,<br>surveying and technical<br>building services                             | 0.098                          | 0.077                          | 0.080                    | 28.41<br>(11.11)              |
| Natural sciences,<br>geography and<br>informatics                                                       | 0.024                          | 0.013                          | 0.012                    | 28.55<br>(7.84)               |
| Traffic, logistics, safety<br>and security                                                              | 0.015                          | 0.029                          | 0.033                    | 31.28<br>(16.40)              |
| Commercial services,<br>trading, sales, the hotel<br>business and tourism                               | 0.130                          | 0.161                          | 0.138                    | 25.04<br>(7.24)               |
| Business organization,<br>accounting, law and<br>administration                                         | 0.123                          | 0.125                          | 0.115                    | 28.69<br>(10.41)              |
| Health care, the social<br>sector, teaching and<br>education                                            | 0.277                          | 0.268                          | 0.284                    | 30.61<br>(12.74)              |
| Philology, literature,<br>humanities, social sciences,<br>economics, media, art,<br>culture, and design | 0.019                          | 0.014                          | 0.007                    | 31.67<br>(18.45)              |
| Observations                                                                                            | 7868                           | 5832                           | 12,035                   | 26,215                        |

Note: Columns 1–3 show the average share of apprenticeships in BR by first digit occupational group of the Classification of Occupations 2010, Column 4 shows the average apprentice wage in these occupations, standard deviation in parentheses.

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