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Abstract

In this paper, we show that an increase in apprenticeship wages reduces the demand for apprentices. We exploit a natural experiment that provides exogenous variation in apprenticeship wages combined with discontinuities in the eligibility criteria (firms with fewer than 15 employees are not required to train apprentices). Our main results, based on difference-in-discontinuity methods, indicate that increasing apprenticeship wages from 75% to 100% of the national minimum wage leads to a reduction in the demand for apprentices of 83% in non-eligible firms. The intensive margin analysis, which compares the number of apprentices observed for firms with their regulatory target, shows that the rise in training costs also reduces the demand for apprentices in eligible firms. The impact is considerable for large firms (over 250 employees) and for firms that pay low wages, with estimated effects of 28.8% and 48.2%, respectively.

JEL Classification**:** *I*26, *J*24, *J*30, *M*53.
Keywords**:** *Demand for apprentices, sustaining support, on-the-job training, human capital accumulation*.

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Costos de entrenamiento y demanda de aprendices

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Resumen

En este artículo mostramos que el aumento del salario (apoyo de sostenimiento) de los aprendices reduce su demanda por parte de las firmas. Aprovechamos un experimento natural en Colombia que proporciona la variación exógena en el salario de los aprendices combinada con discontinuidades en los criterios de elegibilidad (las empresas con menos de 15 empleados no están obligadas a capacitar aprendices). Nuestros principales resultados, basados en métodos de diferencia en discontinuidad, indican que incrementar el salario de los aprendices del 75% al 100% del salario mínimo nacional conduce a una reducción de la demanda de aprendices del 83% en las empresas no obligadas a capacitar aprendices. El análisis del margen intensivo, que compara los aprendices observados de las empresas con su objetivo regulatorio (número de aprendices esperados), muestra que el aumento de los costos de capacitación también reduce la demanda de aprendices en las empresas obligadas. El impacto es particularmente alto en las empresas grandes (más de 250 empleados) y las empresas con salarios bajos, con efectos estimados de 28,8% y 48,2%, respectivamente.

***Clasificación JEL*:** *I*26, *J*24, *J*30, *M*53.
***Palabras clave*:** *Demanda de aprendices, apoyo de sostenimiento de aprendices, entrenamiento, acumulación de capital humano.*

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1. Introduction

Apprenticeships and on-the-job training programs are common policies to promote human capital accumulation, increase labor productivity, and boost long-term economic growth.[1] There is abundant evidence to show that apprenticeship programs have positive and economically large impacts along all these dimensions (Arrow, 1964; Barro and Lee, 1994; Acemoglu and Pischke, 1999; Lucas, 2002; Zwick, 2006; De Grip and Sauermann, 2012; McKenzie, 2017; Adhvaryu, Kala, and Nyshadham, 2018; Card, Kluve, and Weber, 2018; Dostie, 2018; Carranza & McKenzie, 2024; Ma, Nakab, and Vidart, 2024; Torm, 2024). One key aspect of these training programs is that the costs of training are often shared between firms, apprentices, and governments, especially when apprentices acquire general skills (Becker, 1964). For instance, apprenticeship wages can be set below market rates to transfer some of the training costs to apprentices. Likewise, subsidies for firms that hire apprentices can transfer training costs to the government. While the efficacy of such policies in increasing the demand for apprentices depends on the wage elasticity, the evidence on this matter remains scarce. Within this framework, cutting firms' training costs is compatible with boosting the demand for apprentices (Wolter, Mühlemann, and Schweri, 2006; Albaek, 2009; Fenizia, Li, and Citino, 2024).

This paper assesses the causal impact of the cost of training on the demand for apprentices. We study the case of Colombia, where the apprenticeship market is heavily regulated. We exploit two key aspects of the regulation providing exogenous variation. First, apprenticeship wages vary depending on the national unemployment rate. This design led to a large and exogenous increase in the wage of apprentices in 2014, from 75% to 100% of the country's minimum wage (MW). Second, training apprentices is only mandatory for firms with 15 employees or more, creating discontinuity in the eligibility criteria of firms. Our research strategy combines rich administrative data from the social security records (PILA in Spanish) and two empirical approaches, difference-in-differences (Diff-in-Diff) and difference-in-discontinuity (Diff-in-Disc), comparing eligible and non-eligible firms, before and after the wage rise; see Angrist and Lavy (1999), Black (1999), and, more recently, Grembi, Nannicini, and Troiano (2016), Picchetti, Pinto, and Shinoki (2024), and Takahashi (2024). We also estimate the intensive margin effects for firms of all sizes, comparing the number of apprentices in each firm to the firm's regulatory target (i.e. the expected number of apprentices).

[1] For comprehensive reviews of on-the-job training and apprenticeship programs, see Bishop (1996) and Wolter & Ryan (2011).

Our main findings show that the rise in apprenticeship wages led to sharp cuts in the demand for apprentices. In our preferred specification, based on the Diff-in-Disc model, the estimated effect oscillates between −0.092 and −0.104 apprentices per establishment, equivalent to cuts in the demand for apprentices of between 73.6% and 83.2%. The implied elasticity of the demand for apprentices is close to −2.5, or −2.1 if we consider the very increase in the MW in 2013, for firms that are not required to train apprentices. The event study estimations indicate that common trends assumptions are satisfied and that the effect on the demand for apprentices is persistent over time. Moreover, the main findings are robust to alternative specifications and bandwidth selections.

For firms that are required to train apprentices, the mandatory number of apprentices varies depending on the number of regular employees. In Section 5.2, we exploit this variation to estimate the intensive margin effects of the wage rise, comparing the observed number of apprentices in firms with their regulatory targets. Our results indicate that the demand for apprentices also dropped in firms that are required to train apprentices. Compared to their regulatory target, the average firm cut apprenticeships by 24%, with an elasticity of the demand for apprentices of −0.72 or −0.62 if we consider the increase in the MW in 2013. The impact is particularly large in large firms (those with more than 250 employees) and low-wage firms, with estimated effects of 28.8% and 48.2%, respectively.

These findings are in line with previous studies showing that high costs of training can lead to lower demand for apprentices (Blatter et al., 2016; Aepli and Kuhn, 2021; Caicedo, Espinosa, and Seibold, 2022). Our paper is particularly related to Caicedo et al. (2022), who exploit previous reforms to the Colombian apprenticeship regulations to show that, given high unobserved costs of training, firms with highly skilled workers are less likely to hire apprentices. Our results, based on an exogenous shift in apprenticeship wages, confirm that firms' demand for apprentices is sensitive to changes in both the observed and unobserved costs of training. Moreover, large firms, which face potentially higher training costs, are particularly responsive, both in Caicedo et al. (2022) and in our paper. One of the main advantages of our exercise is that we use the whole universe of formal firms (not just in the manufacturing sector, as in previous studies), allowing us to compare eligible and non-eligible firms, before and after the wage rise.

More generally, our paper also relates to the literature on the minimum wage. We provide new evidence of the negative wage elasticity of labor demand, even in very regulated labor markets, such as that of apprenticeships. Moreover, our findings are aligned with studies showing that changes in the general minimum wages can also increase the cost of training, and therefore affect the incentives for firms to train apprentices (Leighton and Mincer, 1981; Hashimoto, 1982; Grossberg and Sicilian, 1999;

Neumark and Wascher, 2001; Arulampalam, Booth and Bryan, 2002; Neumark and Nizalova, 2007; Bellmann et al., 2017; Haepp and Lin, 2017; Hara, 2017; Schumann, 2017).[2]

This paper proceeds as follows. In Section 2, we review some of the literature and present a conceptual framework for modeling the demand for apprentices. In Section 3, we describe the apprenticeship program in Colombia. In Section 4, we present the data and the empirical strategies. In Section 5, we present the results. We conclude in Section 6.

2. Conceptual framework

The literature on the positive impacts of apprenticeships and on-the-job training programs is abundant. Firms in both developed and developing countries benefit from these programs by increasing productivity (Zwick, 2006; Dionisius et al., 2009; Mohrenweiser and Zwick, 2009; Sepúlveda, 2010; De Grip & Sauermann, 2012; Dostie, 2018; Ospino, 2018). Apprenticeships have medium- and long-term benefits in terms of employability and earnings (Frazis and Loewenstein, 2005; Almeida and Faria, 2014; McKenzie and Woodruff, 2014; McKenzie, 2017; Adhvaryu et al., 2018; Card et al., 2018; Alfonsi et al., 2020; Carranza & McKenzie, 2024; Doerr and Novella, 2024; Ma et al., 2024).[3]

One key question when it comes to apprenticeships is who pays for the training. The answer depends on the types of skills provided. The formal training of apprentices can be either general or firm-specific. General training benefits all firms, as the marginal productivity of workers increases in any firm that might engage the apprentice. Specific training increases the labor productivity of workers only in the firm that provides such training. Firms have fewer incentives to provide general training, and it can be optimal that training costs are at least partially assumed by apprentices – or governments (Becker, 1964; Booth and Bryan, 2002). Acemoglu and Pischke (1998, 1999, 2003) provide different frameworks in which firms bear an important share of the training costs for skills that correspond to general human capital formation. Such situations – linked to information asymmetries, moral hazard, collective bargaining, firm-specific and general skills, and search costs – drive compressed wage structures.

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[2] Multiple studies have found negative effects on minimum wage on training and human capital accumulation in the United States (Leighton and Mincer, 1981; Neumark and Wascher, 2001; Fairris and Pedace, 2004), Germany (Bellman et al., 2017; Schumann, 2017), Canada (Alessandrini and Milla, 2024), United Kingdom (Arulampalam, Booth, and Bryan, 2002, 2004), and China (Haepp and Lin, 2017). In non-competitive labor markets, however, minimum wages can increase human capital accumulation, as these incentivize firms to train their less-qualified workers (Acemoglu and Pischke, 1999, 2003).

[3] Medina and Núñez (2005), using the Life Quality Survey for Colombia (ECV), estimate the effects of training (of apprentices at SENA) on the monthly income.

We use a partial equilibrium model, in the spirit of Caicedo et al. (2022), to rationalize why an increase in the cost of training reduces the demand for apprentices. Suppose that a firm i that produces good y in sector j has a production function given by

$$y_{i,j,t} = f\left(l^{r}_{i,j,t}, \varphi^{a}_{i,j} l^{a}_{i,j,t}; z_{j,t}\right),$$

where $l^{r}_{i,j}$ is the number of regular workers, $l^{a}_{i,j}$ is the number of apprentices at the practical training phase, $\varphi^{a}_{i,j}, \in (0,1]$ is the productivity of apprentices relative to regular workers, and $z_{j,t}$ is managerial ability. The production function exhibits constant returns to scale in l^{r}, l^{a}, and z. If we also assume that the price of the good, the wages of the regular workers, and the wages of the apprentices are, respectively, given by p_j, w^{r}_{j}, and w^{a}, then the profits function to maximize by the firms in the arguments l^{r} and l^{a} corresponds to

$$\textstyle\sum_{t=0}^{\infty} 1/(1+\tilde{r})^{t} \left[p_{j,t} y_{i,j,t} - w^{r}_{j,t} l^{r}_{i,j,t} - w^{a}_{t} l^{a}_{i,j,t}\right],$$

where $\tilde{r}$ is the constant real interest rate. If we take into account that, according to the regulations, the apprenticeship wage (sustaining support) is a fraction $\rho \in (0,1]$ of the minimum wage, $w^{a} = \rho w^{min}$, and if we further parametrize the production function as

$$y_{i,j,t} = {z_{j,t}}^{\tau} \left(l^{r}_{i,j,t}\right)^{\omega} \left(\varphi^{a}_{i,j} l^{a}_{i,j,t}\right)^{\varepsilon},$$

assuming homogeneity of degree $(\omega + \varepsilon) \in (0, 1)$ in $l^{r}$and l^{a}, after standard manipulations of the first-order conditions we arrive at the demand for apprentices given by

$$l^{a*}_{i,j,t} = z_{i,j,t}^{\frac{\tau}{1-\omega-\varepsilon}} \left(\frac{\omega}{\widetilde{w}^{r}_{j,t}}\right)^{\frac{\omega}{1-\omega-\varepsilon}} \left(\frac{\varepsilon}{\rho \widetilde{w}^{min}_{t}}\right)^{\frac{1-\omega}{1-\omega-\varepsilon}} \varphi^{a}_{i,j}{}^{\frac{\varepsilon}{1-\omega-\varepsilon}}.$$

Thus, this simple theoretical framework allows us to observe that the higher wages of apprentices ($w^{a} = \rho w^{min}$), through a higher ρ or higher minimum wage ($\widetilde{w}^{min}_{t}$), will lead to smaller demand. At the same time, higher values of the productivity level of apprentices, $\varphi^{a}_{i,j}$, will increase the demand for apprentices.[4]

The expansion path is given by $l^{r*}_{i,j,t}/l^{a*}_{i,j,t} = (\omega/\varepsilon)\,(w^{a}/\widetilde{w}^{r}_{j,t})$. Thus, if $\widetilde{w}^{r}_{j,t} = w^{min}$, this path should satisfy $l^{r*}_{i,j,t}/l^{a*}_{i,j,t} = (\omega/\varepsilon)\rho$. This implies that the optimal path is a fraction ρ of the relative returns in the production function of regular workers to the return of apprentices. Given the increase in sustaining support that occurred in 2014 that made $\rho = 1$, the relative demand to be optimal should satisfy: $l^{r*}_{i,j,t}/l^{a*}_{i,j,t} = (\omega/\varepsilon)$.

[4] The own-price elasticity, $(\partial l^{a}_{i,j,t}/\partial w^{a} \times w^{a}/l^{a}_{i,j,t} = \partial l^{a}_{i,j,t}/\partial \rho w^{min} \times \rho w^{min}/l^{a}_{i,j,t})$, is given by $-(1-\omega)/(1-\omega-\varepsilon)$, as is well established.

The previous set-up assumes that the firm is free to choose the number of apprentices that maximizes its profits. However, as we will see, this is not always the case, because, due to regulations, the non-optimal demand for apprentices should comply with $l^{a}_{i,j,t} \geq \lambda_1 l^{r*}_{i,j,t}$, where $l^{r*}_{i,j,t}$ is the optimal demand for regular workers and λ_1 is the parameter according to which firms are obliged to have one apprentice for every 20 regular workers and one more apprentice for a fraction of 10 or higher that does not exceed the next 20; thus, $\lambda_1 \approx 0.05$. Otherwise, the firm must pay a fine (see Caicedo et al., 2022).

3. Apprenticeships in Colombia

Apprenticeship programs in Colombia have existed for a long time. The main training programs are provided by the National Apprenticeship Service (SENA, in Spanish), which was created in 1957.[5] These training programs include technical training, technical specialization, technology training, and technological specialization. SENA not only offers training courses but also regulates the demand for apprentices and oversees the matching process between trainees and firms. The system has undergone several modifications and restructurings. At present, the legal framework is supported by Law 789 of 2002. In general, the system offers a mix of general and firm's specific human capital formation, where firms in the formal sector in Colombia are obliged by the regulation to have apprentices and to cover most of the cost of training.[6]

The Apprenticeship Contract is a cornerstone of the system. This contract establishes a relationship, for a period not exceeding two years, between a sponsoring firm and an apprentice who receives, from the authorized institution, the theoretical and practical training required for specific occupations. Such training allows the apprentices to work in different activities for the firm such as administrative, operational, commercial, or financial management. According to the law, all firms carrying out any type of economic activity, other than construction, and employing no fewer than 15 workers, are obliged to hire apprentices.[7] The training process is carried out in two phases: a teaching phase, which is theoretical

[5] There are also some private institutions that meet the training conditions recognized by the government.

[6] Complementary training programs have also been implemented in Colombia. Attanasio, Kugler, and Meghir (2011) evaluated the randomized training program for disadvantaged youth called "Youth in Action – Jovenes en Acción" implemented in 2005. This program provided three months of in-classroom training and three months of on-the-job training to people aged between 18 and 25 from the two (out of six) lowest socioeconomic strata of the population. The authors found positive effects in earnings and more employment opportunities for women. Attanasio et al. (2017) found that these positive effects are persistent, especially the positive effects on formal participation and earnings (Kugler et al., 2022). Similar results were found by Groh et al. (2016) in the case of Jordan, when analyzing the wage subsidy voucher randomly assigned to female community college graduates.

[7] The industrial and commercial firms of the government and those of mixed economy (public and private) of the national or subnational orders are also covered by the law and, consequently, are obliged to have apprentices. Other public entities will not be subject to the apprenticeship regulation, except in cases determined by the government.

and carried out in the classroom, and a practical phase, which is carried out in the workplace (i.e. on-the-job training).

The norm establishes that medium and large firms are obliged to offer contracts to and to train apprentices every year. Firms must have one apprentice for every 20 regular workers and one more for a fraction of ten workers or more that does not exceed the next 20. Thus, firms that have between 15 and 20 workers will have one apprentice while those with fewer than 15 employees are not required by the law to have any. The number of employees in the previous semester is the basis for determining the quota of apprentices that firms must meet. When firms opt not to hire apprentices, they must pay monetary compensation.[8]

The wage of apprentices, or sustaining support, is also determined by law. During the teaching phase, the students receive remuneration from the firm, equivalent to at least 50% of the legal monthly minimum wage (MW). During the practical phase, the apprentices' sustaining support is also tied to the MW, but also depends on the average national unemployment rate of the previous year. In fact, if the unemployment rate in Colombia was equal to 10% or higher, then apprentices receive 75% of MW; however, if it was less than 10%, then the sustaining support is equivalent to 100% of the MW (see Decree 451 of 2008).[9] In 2013, for the first time in this regulation period, the national unemployment rate was 9.6%, implying that the sustaining support was 100% of the MW for apprentices in 2014.

Therefore, in this paper we exploit the exogenous variation on apprenticeship wages that occurred in 2014, and the discontinuity in the eligibility criteria for firms – firms of 15 employees – to evaluate the causal effect on the demand for apprentices. Our empirical strategies Diff-in-Diff and Diff-in-Disc allow us to compare eligible and non-eligible firms, before and after the wage rise. Section 4.2 presents the details of our empirical strategies.

4. Data and empirical strategies

4.1. Data

We use a rich administrative data set comprised of social security records (PILA, in Spanish) from Colombia, which include all formal workers between 2009 and 2018. Using PILA, we build an

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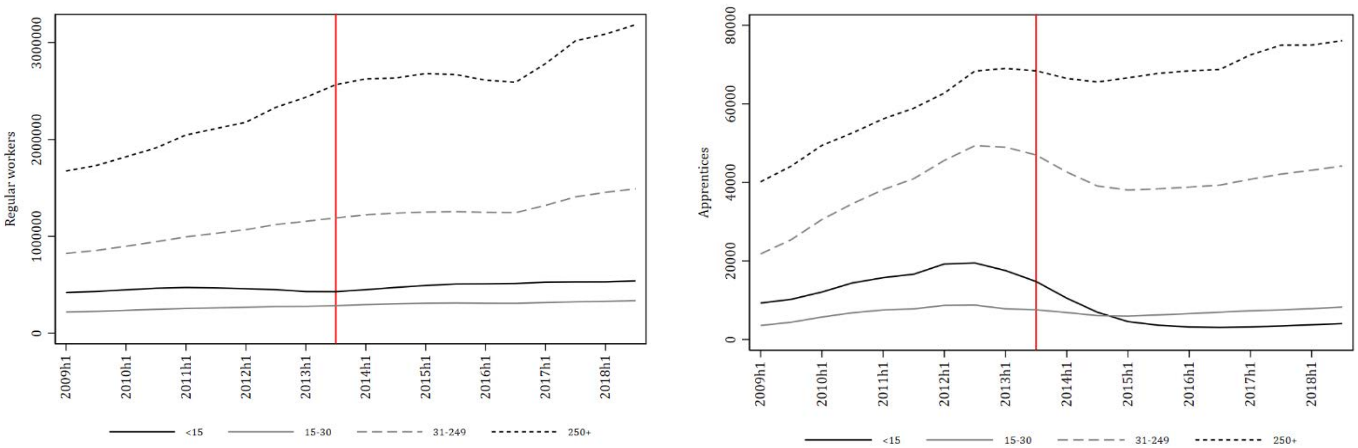
[8] Those firms that decide to pay a monetary compensation, should pay a monthly fee resulting from multiplying 5% of the total number of workers, excluding independent or temporary workers, by a current Legal Monthly Minimum Wage (MW). If monetization is partial, this will be proportional to the number of apprentices who stop doing the internship to meet the mandatory minimum quota.

[9] If the apprentices are undergraduate students, their support cannot be lower than 100% of the MW. The number of undergraduate students in practice, cannot be more than 25% of the apprentices they are allowed to have according to the law.

employer–employee panel and identify the number of workers and apprentices in each plant. In Figure 1, Panel A presents the number of regular workers and Panel B shows the number of apprentices, by different sizes of plants since 2009, linked to firms that make up the balanced panel between 2008 and 2018.[10] As observed across firms of all sizes, the number of regular workers shows an upward trend over time, with a slight slowdown between 2015 and 2017 (Panel A). The time path of the number of apprentices shows an important growth between 2009 and 2013, followed by a significant decline in 2014 across firms of all sizes. Since then, the number of apprentices has been relatively stable, with an increasing trend after 2016; however, it did not reach pre-2014 levels, especially for firms with fewer than 250 employees (Panel B). Note that this reduction was not followed by a reduction in the number of regular workers, which by contrast has an upward-sloping trend across the sample.

Figure 1. Number of apprentices and regular workers

Panel A: Number of regular workers **Panel B: Number of apprentices**



Notes: The vertical line corresponds to the beginning of 2014 when the sustaining support for apprentices in the practical phase increased from 75% to 100% of the MW. The number of apprentices includes those in both theoretical and practical phases.
Source: PILA, and authors' own calculations.

Panel B of Figure 1 shows an interesting difference in the dynamic of apprentices between firms with fewer than 15 employees (i.e. firms that are not obliged to have apprentices) compared with firms of between 15 and 30 workers, which are obliged. The figure shows that the number of apprentices was increasing before 2014. However, since 2014, there has been a significant reduction in the number of apprentices in firms with fewer than 15 regular workers, which are exempt from the regulation requiring them to employ apprentices. Such dynamics contrast with the stable number of apprentices in firms of a relatively similar size (i.e. firms with between 15 and 30 regular workers). Because these firms are

[10] We consider only firms that exist before 2014 (i.e. before the exogenous change in the sustaining support for apprentices) and continue up to the end of the sample period. For the estimations, we also exclude firms in the 99th percentile of apprentice distribution.

required to comply with the law or pay monetary compensation, demand for apprentices remains unchanged despite the increase in their costs. Otherwise, the reduction in their demand for apprentices would likely mirror that observed in firms where employing apprentices is not mandatory.[11]

4.2. Empirical strategies

To gauge the impact of the increase in apprenticeship wages on labor demand for them, we begin our analysis with a Diff-in-Diff estimation. This methodology compares the differences in the demand for apprentices between treatment and control groups before and after 2014 when the exogenous change in the sustaining support for apprentices (from 75% of MW to 100% of MW, which corresponds to an increase of 33.3%[12]) took place. In this case, we refer to firms with fewer than 15 regular workers as the treated group, and to firms with between 15 and 30 employees as the control group. We have the following specification:

$$y_{it} = \alpha_0 + \delta_0 Treat_i + \gamma_0 Post_t + \beta_0 Post_t \times Treat_i + \epsilon_{it}. \quad (1)$$

Here, y_{it} represents the number of observed apprentices in firm i in period t; $Treat_i$ is a dummy variable that takes the value of 1 when the firm has fewer than 15 regular workers, and 0 when it has between 15 and 30 workers; $Post_t$ is a dummy variable that takes the value of 1 after the second semester of 2013 and 0 otherwise. The parameter of interest, β_0, represents the difference in the demand for apprentices in the treated group compared with the control group after 2014 when the increase in the cost of apprentices occurred. Alternative specifications of the model in equation (1) include firm fixed effects (δ_i) and time fixed effects (γ_t).

We further exploit the discontinuity in the eligibility criteria depending on the size of firms with a Diff-in-Disc approach, following Grembi et al. (2016), Picchetti et al. (2024), and Takahashi (2024). Recall that firms with 15 or more workers are obliged to train at least one apprentice, while those with fewer than 15 workers are not expected to train any apprentices. The running variable (s_i) is the normalized size of the firm (firm size minus 15), which takes positive values for the control firms and negative for the treated firms. Our main specification controls a polynomial of the running variable, as well as its interaction with each of the Diff-in-Diff terms:

$$y_{it} = \alpha_0 + \alpha_1 s_i + (\delta_0 + \delta_1 s_i)Treat_i + [(\gamma_0 + \gamma_1 s_i) + (\beta_0 + \beta_1 s_i)Treat_i] \times Post_t + \epsilon_{it}. \quad (2)$$

[11] Tables A1 and A2 in Appendix A present some descriptive statistics for different firm sizes and subsample periods used in the estimations.
[12] In addition, the nominal MW at the end 2013 increased by 4% according to the agreement in the Permanent Commission for the Agreement on Salary and Labor Policies. Thus, this implies a total increase in the sustaining support of 38.6%.

As in equation (1), β_0 represents our parameter of interest and reflects the difference between treated and control firms, once the wages of apprentices are raised. Alternative specifications include firm fixed effects (δ_i) and time fixed effects (γ_t). Because firms with over 30 employees are required to hire two or more apprentices, we restrict the sample to firms between 1 and 30 employees. The main advantage of this approach, compared with the traditional Diff-in-Diff approach, is that it assigns more weight to firms located closer to the discontinuity threshold, effectively providing more precise estimates of the local effect of the policy.

We also estimate the dynamic effects with event study models providing information on both the pre-treatment period and the dynamic effect. For this, the dummy variable $Treat_i$ is interacted with a group of dummy variables for each semester between 2009 and 2018. In this case, the reference period to compare the effects of the exogenous change on the wage of apprentices is the second semester of 2013. The empirical model corresponds to

$$y_{it} = \alpha_0 + \sum_{\tau=1}^{T} \beta_m Treat_i \times 1\{t = \tau\} + \delta_i + \gamma_t + \varepsilon_{it}. \quad (3)$$

We also estimate an analogous model for the Diff-in-Disc specification, which controls for the interactions between the discontinuity running variable (s_i) and all the event study variables. This model assigns more weight to firms located near the discontinuity threshold:

$$y_{it} = \alpha_0 + \sum_{\tau=1}^{T} \beta_m Treat_i \times 1\{t = \tau\} + \sum_{\tau=1}^{T} \alpha_m Treat_i \times 1\{t = \tau\} \times s_i + \delta_i + \gamma_t + \varepsilon_{it}. \quad (4)$$

In Section 5.2, we explore the intensive margin effects for firms of all sizes. As seen in Panel B of Figure 1, after 2014 there was a reduction in the number of apprentices in firms with more than 30 regular workers, which are excluded from the first analysis. We explore the effect on the demand for apprentices in all firms with an intensive margin analysis. To achieve this aim, we compare the number of apprentices observed with the number of apprentices expected at a firm level. In this case, we organize the data such that we have two observations for each firm and period (semester): the actual number of apprentices, which represents the treatment group ($k = 1$) and the expected number of apprentices, which represents the control group ($k = 0$). The latter is computed, according to the regulations, as the number of regular employees in the previous semester was divided by 20. Thus, we estimate the following model[13]

[13] Given the lack of information on the number of excluded occupations for the calculation of the apprentice quota (in PILA and from the SENA) we use the total number of regular employees as a reference for this calculation. Aggregate statistics from SENA allow us to estimate that excluded occupations are close to 6.5% of the total occupations. However, given that there is no regulatory change related to this exclusion (during the sample period), we carry out the estimation under the assumption that the time sector fixed effect captures this heterogeneity without affecting our main results.

$$y_{ikt} = \alpha_0 + \delta_0 Treat_{ik} + \gamma_0 Post_t + \beta_0 Treat_{ik} \times Post_t + \delta_i + \gamma_t + \varepsilon_{it}, \quad (5)$$

where y_{ikt} represents the number of observed ($\forall_k = 1$) and expected ($\forall_k = 0$) apprentices in firm i in period t. $Treat_{ik}$ is a dummy variable that takes the value of 1 when we refer to observed apprentices ($\forall_k = 1$) and 0 when we refer to expected apprentices ($\forall_k = 0$) in firm i. $Post_t$ is a dummy variable that takes the value of 1 after the second semester of 2013, and 0 otherwise. The parameter β_0 is the effect on the observed demand for apprentices relative to the expected demand for apprentices when there is a change in apprenticeship wages. The regression in expression (5) also includes fixed effects at firm (δ_i) and time (γ_t) levels that represent the unobserved characteristics of each firm and the common shocks. Errors are clustered across firms. These regressions are estimated for all firms and for subsamples of firms divided by the average number of employees (size of firms) and the average range of wages. The latter dimension of the analysis is carried out under the assumption that wages are a proxy of the firms' productivity; in this case, the median of the wages by firm is used as a cut-off.

5. Results

5.1. Main results

Columns 1 and 2 of Table 1 show the Diff-in-Diff estimations with and without fixed effects [equation (1)]. As we can observe, the estimated value of the parameter of interest, β_0, fluctuates between −0.209 and −0.233; the latter result is obtained when controlling for time and firm fixed effect. Thus, the exogenous change in apprenticeship wages induced a reduction of 0.233 apprentices per establishment. In other words, the introduction of the measure in 2014 produced adverse effects in the demand for apprentices in firms not obliged to train apprentices. Columns 3 and 4 present the results of our preferred estimation (Diff-in-Disc). Notice that, in this case, the magnitude of the coefficients is lower, as we are assigning more weight to firms located closer to the discontinuity threshold. Column 3 shows the ordinary least-squares estimation of equation (2), while Column 4 presents the results controlling by firm and time fixed effects, in which case the estimation is around −0.104 apprentices per establishment.

This result implies that, compared to the control group, there was a reduction on the demand for apprentices on the treated group (firms that are not obliged by Law to have apprentices) of around 0.104 apprentices per establishment; given that in the second semester of 2013 the average number of apprentices in the treatment group was 0.125 per establishment, this implies a reduction of demand for apprentices of 83% (a reduction on the demand of about 7,934 apprentices). Accordingly, if we recall that the increase of the wage of apprentices was about 33.3%, the elasticity of the demand for apprentices implied by this approach is about −2.5. When we consider the 4% increase in the MW that also took place in 2013, the increase in apprentices wages rise to 38.7%, leading to an elasticity of −2.1.

Table 1. Diff-in-Diff and Diff-in-Disc estimates

Variable	**Apprentices**			
	Diff-in-Diff		**Diff-in-Disc**	
	(1)	**(2)**	**(3)**	**(4)**
Post × Treat	−0.209***	−0.233***	−0.092***	−0.104***
	(0.020)	(0.011)	(0.025)	(0.018)
Treat	−0.277***		−0.005	
	(0.019)		(0.023)	
Post	0.196***		0.108***	
	(0.019)		(0.020)	
Post × Treat × Firm size			−0.012***	−0.014***
			(0.003)	(0.003)
Treat × Firm size			0.028***	
			(0.003)	
Post × Firm size			0.015***	0.017***
			(0.003)	(0.002)
Firm size			0.035***	
			(0.003)	
Constant	0.325***	0.198***	0.116***	0.146***
	(0.019)	(0.005)	(0.019)	(0.007)
Mean 2013-II	0.125	0.125	0.125	0.125
Marginal	1.672	1.864	0.744	0.832
Reduction on apprentices	15,944	17,775	7,095	7,934
Number of control firms	76,288	76,288	76,288	76,288
Number of treated firms	13,512	13,512	13,512	13,512
Firm fixed effects		✓		✓
Time fixed effects		✓		✓
Observations	1,698,505	1,698,499	1,698,505	1,698,499
R^2	0.008	0.327	0.011	0.327

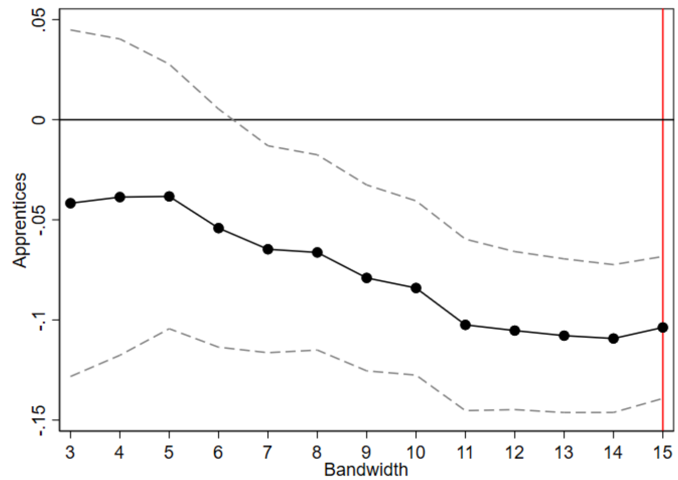
Note: Standard deviations in parentheses. 'Mean 2013-II' refers to the number of apprentices of 2013-II including all firms of the sample. *, **, and * denote statistical significance at the 10%, 5% and 1% levels, respectively.**
Source: PILA; authors' own calculations.

Results are overall robust to the bandwidth selection. Figure 2 presents the Diff-in-Disc estimates for bandwidths between 3 and 15. The estimated coefficients are statistically significant and similar in magnitude for all bandwidths larger than 6. Alternatively, one might implement an optimal bandwidth as suggested by the test of Calonico, Cattaneo, and Farrell (2020). The results using the one mean squared error (OMSE) optimal bandwidth, and coverage error rate (CER) optimal bandwidth procedures indicate a bandwidth of 15 as optimal.[14] Moreover, our results are also robust to account for any effect of changes in the MW within the firm. To do so, we include the Kaitz ratio, at firm level, lagged for two semesters to reduce any potential endogeneity, finding similar estimated effects (see Appendix B).

[14] The OMSE method chooses the bandwidth that minimizes the MSE of the estimator, and CER method chooses the bandwidth that minimizes the CER of the confidence intervals (the CER is the difference between the nominal confidence level and the actual coverage probability).

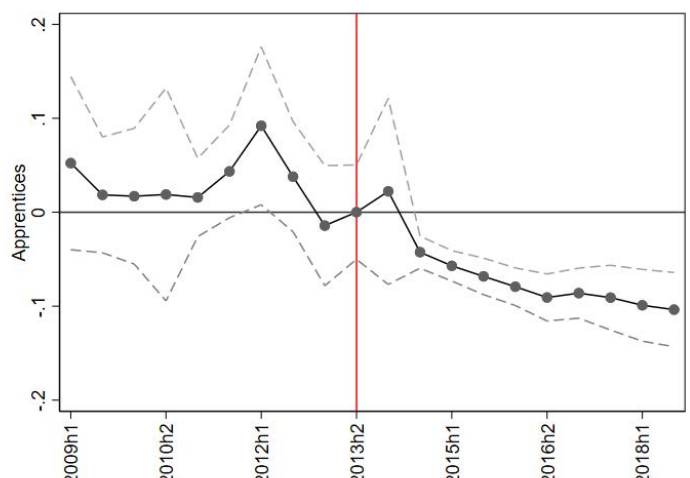
The first approach to the dynamic effect of the wage rise is to estimate a regression discontinuity model period by period. Figure 3 presents the estimated coefficient for a fixed bandwidth of 15. As we expected, between 2009 and 2013 there is no significant difference in the demand for apprentices between the control group and the treatment group. However, after the second semester of 2014, we observed a significant difference in the demand for apprentices between these two groups. These results imply that compared with the control group, there was an increasing reduction in the demand for apprentices in the treated group (firms that are not obliged by law to have apprentices) that converges to −0.1 apprentices per firm at the end of the sample. These coefficients are very similar to the ones presented in the previous estimations (see Table 1).

Figure 2. Sensibility of Diff-in-Disc estimations to bandwidths



Note: The vertical line corresponds to the beginning of 2014 when the sustaining support for apprentices in the practical phase increased from 75% to 100% of MW.
Source: PILA; authors' own calculations.

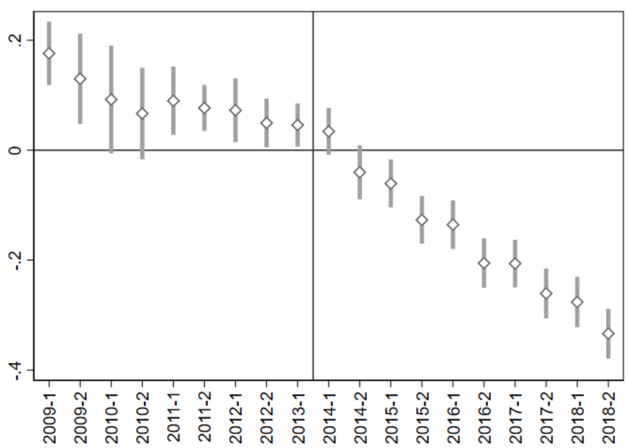
Figure 3. Regression discontinuity period by period



Note: Each coefficient corresponds to a separate regression discontinuity model, with a fixed bandwidth of 15. The vertical line corresponds to the beginning of 2014 when the sustaining support for apprentices in the practical phase increased from 75% to 100% of the MW.
Source: PILA; authors' own calculations.

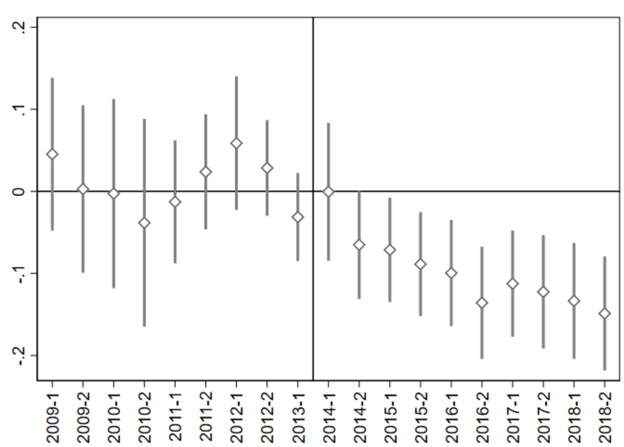
Figures 4 and 5 present the event study estimates from the Diff-in-Diff and Diff-in-Disc specifications, respectively. Note, first, that the Diff-in-Diff results exhibit some pre-trends while the Diff-in-Disc results do not. This highlights the extent to which exploiting the discontinuity in the eligibility criteria can lead to a more precise control group, and therefore a better estimation. As for the dynamic effects, both models indicate that the impact of the wage rise is persistent over time. In the case of the Diff-in-Disc design, we find that firms that are not obliged to have apprentices reduce their demand by 0.15 apprentices per establishment at the end of 2018.

Figure 4. Diff-in-Diff event study estimates



Note: The vertical line corresponds to the beginning of 2014 when the sustaining support for apprentices in the practical phase increased from 75% to 100% of the MW.
Source: PILA; authors' own calculations.

Figure 5. Diff-in-Disc event study estimates



Note: The vertical line corresponds to the beginning of 2014 when the sustaining support for apprentices in the practical phase increased from 75% to 100% of the MW.
Source: PILA; authors' own calculations.

5.2. Intensive margin effects

In this subsection, we explore the intensive margin effects for firms of all sizes, comparing the number of apprentices observed with the number of apprentices expected at a firm level [see equation (5)]. Column 1 of Table 2 presents the results with all firms while the models in Columns 2–5 show the results for firms according to the number of employees. Similarly, Columns 6 and 7 contain the estimated coefficients according to the average wages paid by the firms to their workers. The coefficient of the variable represents the causal effect of the change in apprenticeship wages on the number of apprentices hired compared to the expected number. This result indicates that as a result of the change in the sustaining support for apprentices after 2014, in all firms, the number of observed apprentices per establishment, with respect to the expected number, is about 0.290 less, on average. This result implies a reduction of 24% (0.290/1.222) in the level of apprentices per average firm compared to the observed number in the second semester of 2013, which represents a reduction in the number of apprentices of 31,707. The elasticity of the demand for apprentices for an average firm implied by this approach is about −0.72 (0.24/0.333), or −0.62 if we consider the full increase in the wage of apprentices that took place in 2014.

Table 2. Intensive margin analysis

Variable	**All firms**	**Number of employees**				**Wages**	
		<15	**15–30**	**31–249**	**250+**	**Low wages**	**High wages**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
Treat	−0.903***	−0.124***	−0.689***	−1.519***	−19.684***	−0.565***	−1.243***
	(0.031)	(0.004)	(0.019)	(0.036)	(1.096)	(0.029)	(0.054)
Treat × *Post*	−0.290***	−0.077***	−0.035*	−0.329***	−7.371***	−0.293***	−0.283***
	(0.018)	(0.004)	(0.020)	(0.041)	(0.610)	(0.024)	(0.026)
Post	1.301***	0.112***	0.529***	2.487***	28.631***	0.560***	1.994***
	(0.042)	(0.005)	(0.020)	(0.056)	(1.377)	(0.037)	(0.074)
Mean 2013-II	1.222	0.125	0.509	2.956	25.576	0.608	1.855
Marginal	−0.237	−0.617	−0.069	−0.111	−0.288	−0.482	−0.153
Reduction in apprentices	31,707	5,874	473	5,040	19,942	16,047	15,021
Number of firms	107,848	76,288	13,512	15,320	2,728	54,769	53,079
Observations	4,085,750	2,883,118	513,892	582,356	105,814	2,042,864	2,042,886
R^2	0.007	0.008	0.045	0.060	0.097	0.005	0.009

Note: Standard deviations in parentheses. All estimations control by firm fixed effects and time fixed effects. 'Mean 2013-II' refers to the number of apprentices of 2013-II including all firms of the sample. *, **, and * denote statistical significance at the 10%, 5% and 1% levels, respectively. Source: PILA; authors' own calculations.**

According to the results in Columns 2–5, the effect of the change in the sustaining support for apprentices increases, in general, with the size of firms. Establishments with more than 250 employees present a reduction of 29% per establishment in the demand for apprentices, compared to the expected level of apprentices before the change in apprenticeship wages. In the case of firms assorted by the average wage, the results show that the marginal effect (after 2014) is lower in the case of firms with high wages (15%), while the higher reduction is observed in less productive firms or firms with low wages (48%).

Table C2 of Appendix C also presents the results of regressions including the Kaitz ratio to account for any effect of changes in the MW within the firm in the demand for apprentices (see the descriptive statistics of the Kaitz index[15] in Table C1). We should recall that apprenticeship wages are linked to the MW, so the demand for apprentices might potentially be affected by such a variable, which is set on an annual basis in Colombia (see the theoretical model in Section 2). To remedy the potential endogeneity of the Kaitz ratio, this variable is included in the regression lagged for two semesters. Although the results remain similar, it is worth mentioning that the inclusion of the Kaitz ratio in the regression reduces slightly the effect.[16] In this case we find a reduction of 20% in the level of apprentices per average firm compared to the observed in the second semester of 2013.

6. Discussion and conclusions

We study a natural experiment in Colombia that provides exogenous variation in apprenticeship wages, as well as a discontinuity in the eligibility criteria of firms, to assess the effect of training costs on the demand for apprentices. Our main results, based on a Diff-in-Disc design, indicate that an increase of 33.3% in wages led to a sharp cut of 83% in the demand for apprentices in firms that are not obliged to have apprentices. This result implies an elasticity of the demand for apprentices between −2.5 and −2.1. We complement our analysis with intensive margin analysis that compares the number of observed apprentices in firms with the firm's regulatory targets (i.e. the number of expected apprentices). The results indicate that even firms that are required to train apprentices reduce the number of apprentices following the wage rise. The impact is particularly sizeable in large firms (more than 250 employees), with a 15.3% reduction in the number of apprentices, and in low-wage firms, with a 48.2% reduction in the number of apprentices.

Our results show that higher training costs that are borne mainly by firms, as in the Colombian case, can have adverse and persistent effects on the formation of human capital, which affects not only labor productivity and long-term growth, but also the future earnings for the new workers. In addition to large rises in wages, like the one we study in this paper, these findings raise questions regarding the

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[15] The descriptive statistics in Table C1 from appendix C show that, according to the median of the Kaitz ratio, the MW is more binding in smaller establishments compared to those with higher number of employees. It is important to mention that these regressions were limited to those firms for which the Kaitz index is bounded by 0 and 1.

[16] Apart from the Kaitz ratio, we also run regressions including controls for sector (ISIC at two-digit level) fixed-effects, however the results do not change with respect to those presented in Appendix B.

implications of other policies that mechanically increase training costs, such as indexing apprenticeship wages to the MW. This point is important because in Colombia the MW is above 85% of the median wage (see Arango and Flórez, 2021) while in OECD countries the Kaitz index is about 50%.

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Appendix A

Table A1. Descriptive statistics by firm size

	Mean	Median
Fewer than 15 workers		
Regular workers	6.62	4.6
	(15.62)	
Observed apprentices	0.04	0
	(1.28)	
Between 15 and 30 workers		
Regular workers	22.24	19.4
	(21.43)	
Observed apprentices	0.42	0
	(2.54)	
Expected apprentices	1.13	1.0
	(1.09)	
Observed minus expected	−0.71	−1.0
	(2.62)	
Between 31 and 249 workers		
Regular workers	80.12	55.6
	(85.38)	
Observed apprentices	2.32	1.2
	(5.76)	
Expected apprentices	4.01	3.0
	(4.28)	
Observed minus expected	−1.68	−1.0
	(6.01)	
More than 249 workers		
Regular workers	591.4	268.0
	(1503.6)	
Observed apprentices	14.70	0.67
	(53.35)	
Expected apprentices	29.36	13.0
	(74.99)	
Observed minus expected	−14.66	−1.5
	(54.43)	

Source: PILA; authors' own calculations.

Table A2. Descriptive statistics by periods

Sample period	**Mean**	**Median**
2009–2018		
Regular workers	42.74	7.0
	(327.05)	
Observed apprentices	1.01	0
	(11.51)	
Expected apprentices	2.05	0
	(16.37)	
Observed minus expected	−1.04	0
	(11.73)	
2009–2013		
Regular workers	37.16	6.6
	(366.17)	
Observed apprentices	0.88	0
	(10.57)	
Expected apprentices	1.77	0
	(14.15)	
Observed minus expected	−0.89	0
	(11.04)	
2014–2018		
Regular workers	48.35	7.5
	(366.1)	
Observed apprentices	1.15	0
	(12.39)	
Expected apprentices	2.34	0
	(18.32)	
Observed minus expected	−1.19	0
	(12.38)	

Note: Standard errors in parentheses.
Source: PILA; authors' own calculations.

Appendix B

Table B1. Diff-in-Diff and Diff-in-Disc estimates controlling for the Kaitz ratio, 2009–2018

Variable	**Apprentices**			
	Diff-in-Diff		**Diff-in-Disc**	
	(1)	**(2)**	**(3)**	**(4)**
Post × *Treat*	−0.196***	−0.210***	−0.098***	−0.101***
	(0.017)	(0.010)	(0.018)	(0.015)
Treat	−0.277***		−0.008	
	(0.017)		(0.016)	
Post	0.406***		0.325***	
	(0.022)		(0.025)	
Post × *Treat* × *Firm size*			−0.011***	−0.014***
			(0.003)	(0.002)
Treat × *Firm size*			−0.031***	
			(0.003)	
Post × *Firm size*			0.013***	0.016***
			(0.003)	(0.002)
Firm size			0.036***	
			(0.003)	
Constant	0.387***	0.176***	0.152***	0.123***
	(0.019)	(0.012)	(0.022)	(0.013)
Mean 2013-II	0.125	0.125	0.125	0.125
Marginal	1.568	1.680	0.784	0.808
Number of control firms	76,288	76,288	76,288	76,288
Number of treated firms	13,512	13,512	13,512	13,512
Firm fixed effects		✓		✓
Time fixed effects		✓		✓
Observations	1,446,218	1,446,121	1,446,218	1,446,121
R^2	0.019	0.419	0.023	0.420

Note: Standard deviations in parentheses. 'Mean 2013-II' refers to the mean number of apprentices of 2013-II including all firms from the sample. *, **, and * denote statistical significance at the 10%, 5% and 1% levels, respectively.**
Source: PILA; authors' own calculations.

Appendix C

Table C1. Kaitz ratio statistics for balanced panel

Size of firms	Number of firms	Number of observations	Mean	Median
Total firms	107,848	3,498,386	0.757 (0.25)	0.829
Fewer than 15 workers	76,288	2,445,162	0.804 (0.23)	0.903
Between 15 and 30 workers	13,512	447,274	0.685 (0.24)	0.713
Between 31 and 249 workers	15,320	512,138	0.624 (0.24)	0.633
More than 250 workers	2,728	93,812	0.590 (0.26)	0.598

Note: The Kaitz index is bound by 0 and 1. When the classification of firms is by wage size, the number of firms with high wages is 53,079, while the number of firms with low wages is 54,769.
Source: PILA; authors' own calculations.

Table C2. Diff-in-Diff estimates controlling for the Kaitz ratio, 2009–2018

Variable	All firms	Number of employees				Wages	
		<15	15–30	31–249	250+	Low wages	High wages
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Treat	−0.979***	−0.135***	−0.716***	−1.579***	−20.608***	−0.657***	−1.279***
	(0.033)	(0.003)	(0.016)	(0.029)	(1.149)	(0.031)	(0.057)
Treat × *Post*	−0.235***	−0.068***	−0.005	−0.258***	−6.179***	−0.215***	−0.252***
	(0.017)	(0.003)	(0.017)	(0.033)	(0.586)	(0.023)	(0.025)
Post	3.631***	0.229***	0.779***	3.336***	29.550***	1.883***	3.482***
	(0.156)	(0.019)	(0.054)	(0.133)	(2.466)	(0.177)	(0.192)
Mean 2013-II	1.222	0.125	0.509	2.976	25.576	0.608	1.855
Marginal	−0.192	−0.545	−0.010	−0.087	−0.242	−0.354	−0.136
Reduction on apprentices	25,668	5,165	69	3,953	16,856	11,775	13,376
Number of firms	107,848	76,288	13,512	15,320	2,728	54,769	53,079
R^2	0.008	0.017	0.071	0.085	0.101	0.007	0.010
Observations	3,535,678	2,445,162	447,274	511,642	93,812	1,686,374	1,812,012

Note: Standard deviations in parentheses. All estimations control by firm fixed effects and time fixed effects. 'Mean 2013-II' refers to the mean number of apprentices of 2013-II including all firms from the sample. *, **, and * denote statistical significance at the 10%, 5% and 1% levels, respectively.**
Source: PILA; authors' own calculations.