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Firm Heterogeneity and the Impact of Payroll Taxes

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Abstract

This paper studies the impact of a large payroll tax cut for older workers in Hungary. Motivated by the predictions of a standard equilibrium job search model, the paper examines the heterogeneous impact of the policy. Employment increases most at low-productivity firms offering low-wage jobs, which tend to hire from unemployment, while the effects are more muted for high-productivity firms offering high-wage jobs. At the same time, wages only increase at high-productivity firms. These results point to important heterogeneity in the incidence of payroll tax cuts across firms and highlight that payroll taxes have a significant impact on the composition of jobs in the labor market.

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1 Introduction

Payroll taxes and employer social security contributions account for just under 40% of the tax wedge in developed countries (OECD, 2022*a*) and there is a longstanding interest in understanding the impact of these policies on employment and wages. The standard approach in public finance suggests that the market-level elasticities of labor supply and demand determine the employment and wage impacts and the incidence of payroll taxes (see e.g. Gruber, 1997; Rothstein, 2010). This approach typically assumes that firms passively accept market-level wages and so the incidence of the payroll tax will be homogeneous across firms and workers. Furthermore, the standard theory does not consider whether tax policies affect the composition of jobs and contribute to the creation of "low wage, bad jobs" or "high wage, good jobs" (Katz and Summers, 1989).[1]

Nevertheless, a growing number of empirical studies highlight that firms play an active role in wage determination and significant wage premium differences are present across employers (see e.g. the early studies of Slichter, 1950 and Lester, 1967; the debate on industry wage premia by Katz, 1986 and Krueger and Summers, 1988; and the evidence on firm wage premia by Abowd, Kramarz and Margolis, 1999 and Card, Heining and Kline, 2013 – for a review see Card, Cardoso, Heining and Kline, 2018). In the presence of job heterogeneity and variation in rents across firms, the evaluation of tax policies, trade policies, and industrial policies should take into account their effect on the composition of jobs (Katz and Summers, 1989; Rodrik and Stantcheva, 2021; Rodrik and Sabel, 2022). The incidence of tax policies can also vary between different firm types, which influences their welfare implications. In this paper, we study whether the impact of payroll taxes varies across firms and whether they change the composition of jobs in the economy.

To illustrate the important role firms could play in shaping the impact of tax policies, we first discuss the effect of such policies in a standard search and matching model with heterogeneous firms (Postel-Vinay and Robin, 2002).[2] In the model, low-productivity firms

[1]The definition of "good" jobs is necessarily slippery (Rodrik and Sabel, 2022). In this paper we focus on variation across firms, rather than variation within firms but across jobs. We use various firm-level proxies including firm-level total factor productivity and firm-level wage premium (Abowd, Kramarz and Margolis, 1999). It has been shown that these measures correlate with better management (Bender et al., 2018) and better non-pecuniary amenities (Sockin, 2022). Furthermore, Sorkin (2018) shows that firms with higher wage premia tend to be better based on workers' revealed preferences as well.

[2]In this framework firm-level rents emerge from search frictions. Nevertheless, rents could reflect information asymmetry (Shapiro and Stiglitz, 1984) or labor market power (Bhaskar, Manning and To, 2002; Manning, 2013; Berger, Herkenhoff and Mongey, 2022). We apply a search framework to illustrate the importance of firm heterogeneity as has been done in earlier papers on search that study the impact of taxes on the allocation of jobs (see e.g. Pissarides, 1985; Smith, 1994; Boone and Bovenberg, 2002; Arseneau and Chugh, 2012; Golosov, Maziero and Menzio, 2013; Kreiner, Munch and Whitta-Jacobsen, 2015; Shephard, 2017; Bagger, Moen and Vejlin, 2021).

tend to hire from unemployment and earn large rents on their workers. At the same time, high-productivity firms can employ more workers as they not only hire from unemployment, but they can also poach workers from low-productivity firms. Poached workers can get a larger share of the surplus or rents as they can use their previous job as an outside option in wage negotiations.

The model highlights that a payroll tax cut increases overall employment and wages just like in the standard framework. Importantly, however, the impact of the policy is heterogeneous across firms. Low-productivity firms, which tend to hire from unemployment, benefit disproportionately from the policy as unemployed workers have limited bargaining power. At the same time, high-quality firms poach more of their workers from other firms, which means that workers are able to claim more of the surplus from the tax cut. Thus, the model suggests that employment effects are concentrated among low-productivity firms, while wage effects are concentrated among high-productivity firms.

We examine the empirical relevance of these predictions by studying the impact of an age-specific payroll tax cut in Hungary. In 2013 the monthly social security contribution decreased by HUF 14,500 ($66) for all over-55 private sector employees.[3] This led to a 5.3% decrease in the labor cost for an average over-55 private sector employee.

Using rich administrative data, we estimate the impact of the policy in a difference-in-differences framework, comparing men above the age cutoff to men just below it.[4] We find a large increase in employment in response to the policy. In response to the 5.3% decrease in labor costs, employment of the treated workers increased by 1.6%, implying a labor demand elasticity of -0.30 (s.e. 0.03). This increase in employment mainly came from non-employment and inactivity. The change in self-employment and public sector employment was limited, reflecting that these workers were ineligible for the payroll tax cut.

In line with the prediction of our illustrative model, we also find substantial heterogeneity across firm types. For a variety of measures of firm quality, the employment-increasing effect of the policy comes from low-quality firms and low-quality jobs, while the employment of older workers in high-quality firms is unchanged. The differential response to the policy by firm type cannot be explained by the lower relative value of the tax cut at high-quality

[3]The average monthly net wage (wage net of employer payroll tax) was HUF 230,700 ($1,045) in Hungary in 2013 (Hungarian Central Statistical Office, 2022), so the tax cut is about 6.3% of the average wage in 2013. A tax cut of equivalent size in the U.S. context would be $3500 per year based on the average salary in 2022 (US Bureau of Labor Statistics, 2022).

[4]We focus on men in the main analysis as for women there was another policy change instituted in 2011 that made it easier to retire earlier than the normal retirement age. That reform could potentially affect women's post-policy employment decisions. Therefore, we have a clearer empirical design by focusing on men. Nevertheless, we also analyze the change in labor market outcomes for women separately and show that the labor market consequences of the tax policy were very similar for them.

firms. Even if the relative decline in labor cost is somewhat larger at low-quality firms, it is still non-negligible at high-quality firms (6% at low-quality firms vs. 4.5% at high-quality firms). The implied employment elasticity with respect to labor cost is statistically different between low-quality firms (-0.53, s.e. 0.05) and high-quality firms (0.01, s.e. 0.06).

We present several additional pieces of evidence to highlight that our results reflect firm heterogeneity and not other factors. First, we examine the effect of the policy throughout the entire wage distribution similarly to Cengiz, Dube, Lindner and Zipperer (2019). We find that employment increased mainly at the bottom of the wage distribution at low-productivity firms, while we find no indication for substantial change in employment in the upper part of the wage distribution where the relative change in labor cost was limited.[5] This suggests that our estimates pick up the effect of the payroll tax cut. Furthermore, we show that heterogeneity in responses is present even if we restrict the sample to similar workers. Even among low-paid workers in low-paying occupations and among less-educated workers, we find different responses to the policy by firm type. This suggests that the differences in responses to the payroll tax cut we uncover reflect firm heterogeneity and not simply the fact that better workers tend to work at better firms.

We also study the impact of the policy on wages. We estimate that the overall pass-through of the policy is small: out of $1 only 22 cents (s.e. 9 cents) benefit workers, while 78 cents (s.e. 9 cents) go to firms. The model predicts that wages should increase for workers at high-productivity firms. This is exactly what we find: there is a significant increase in wages at high-productivity firms, but we find no change in wages at low-productivity firms. At high-productivity firms the pass-through rate is 60 cents (s.e. 13 cents) on the dollar, while at low-productivity firms the pass-through rate is close to zero and statistically insignificant. We also show that the pass-through rate difference is present for workers with low and high levels of education, though it is more prominent for the latter group.

We present several robustness checks to underscore these results. First, we vary the control group definition to make sure that our main estimates are not muted or exaggerated by the variation of the age-window used in the estimation and by potential spillovers to the control group. The main conclusions are unaffected by the choice of the control group.

Second, the comparison of the firm-level relationship between hiring treated workers and untreated workers before and after the reform suggests that firms that hired more treated workers after the reform did not cut their hiring of untreated workers. Accordingly, the policy is likely to have improved overall employment and not just led to substitution of treated workers for untreated ones.

[5]Note that the tax cut was lump sum, which implies that at higher wages the change was smaller relative to total labor costs.

Third, we also study how firms' responses depend on the windfall effects found to be important in the context of tax cuts affecting young Swedish workers (Saez, Schoefer and Seim, 2019). In particular, we show that the change in wages and the incidence differences across firm types do not depend on the size of windfall shocks firms experience and so our findings are robust to controlling for windfall shocks.

Fourth, our results are unlikely to reflect wage rigidities that could potentially bind low-productivity and high-productivity firms differently. Union membership is very low in Hungary and industry-level agreements are rare and set only weak requirements. Furthermore, we find that the heterogeneity between high- and low-productivity firms is present even if we look at employment changes among similarly sized firms. Our estimates do not simply reflect the presence of a binding minimum wage either. The estimated change in employment is not concentrated at the minimum wage. Even among workers earning more than 150% of the minimum wage we find a significant increase in employment at low-productivity firms. This suggests that the employment change does not only come from some low-productivity jobs becoming viable following the payroll tax cut.

These empirical findings together with our theoretical framework point to interesting (and as far as we know so far undocumented) heterogeneity in the incidence of tax cuts. Workers employed by productive firms are able to extract more of the surplus from the tax cut and so the incidence of the tax cut (partly) falls on them. At the same time, older workers who are employed by less productive firms are benefiting from the tax cut through increased hiring, while firms capture a larger share of the surplus for these workers.

Motivated by our findings on the heterogeneous incidence of the policy, we also consider the welfare effects of the policy in the Marginal Value of Public Funds (MVPF) framework (Hendren and Sprung-Keyser, 2020). Because a large share of the tax cut ends up going to employers, particularly at low-productivity firms, the policy has a relatively low MVPF if the policy maker only cares about worker welfare. The MVPF is significantly higher at high-productivity firms with high pass-through rates than at low-productivity firms with pass-through rates close to zero. If we also include the part of the tax cut that goes to employers, the MVPF is higher. Importantly, in this case targeting low-productivity firms with the tax cut has a higher MVPF than targeting high-productivity firms because the employment creation effect dominates the wage effect. Our welfare analysis, therefore, highlights that it is important to take into account how payroll taxes affect the prevalence of good and bad jobs in the economy.

Since parallel to the tax cut for older workers, a tax cut affecting workers under 25 is also introduced, we can compare our estimated responses for older workers to impacts among younger workers. We find that the payroll tax cut increased employment of younger workers

with little impact on wages.[6] We also find heterogeneity patterns similar to those documented for older workers though the differences between high- and low-productivity firms are smaller. We interpret the more muted heterogeneity through the lens of our illustrative model: most younger workers have low bargaining power as they come from unemployment or temporary contracts that cannot easily be used in wage negotiations. As a result, most young workers have a weak bargaining position with limited outside option, thus high- and low-productivity firms are affected similarly by the tax cut.[7] Furthermore, labor market institutions could serve a more important constraint for younger workers, given the large share of them at or slightly above the minimum wage.[8]

Our paper relates to several strands of the literature. First, our study relates to the literature on payroll tax incidence in general. Studies using payroll tax reforms to analyze incidence provide mixed evidence. Some studies find that the burden of the payroll tax is shifted on the workers (Gruber, 1997; Anderson and Meyer, 2000). However, some later studies find that the burden of the payroll tax is mostly borne by the employer (Kugler and Kugler, 2009; Saez, Matsaganis and Tsakloglou, 2012; Saez, Schoefer and Seim, 2019; Ku, Schönberg and Schreiner, 2020; Benzarti and Harju, 2021).[9] Our results highlight that the incidence of payroll taxes depends on the type of firms or workers (young vs. old) studied. Evaluating the incidence of business tax credits Carbonnier, Malgouyres, Py and Urvoy (2022) document some heterogeneity in incidence by worker type, but firm heterogeneity and the effects of the policy on the composition of jobs is mainly ignored in the literature so far.

The paper is also closely related to studies of age-based employment subsidies (Kramarz and Philippon, 2001; Boockmann, Zwick, Ammermüller and Maier, 2012; Huttunen, Pirttilä and Uusitalo, 2013; Egebark and Kaunitz, 2018; Saez, Schoefer and Seim, 2019; Svraka, 2019). Studying the labor market consequences of such policies is particularly interesting given that they target vulnerable groups with relatively low employment rates. Improving the employment and wage prospects of these workers is a policy priority for many govern-

[6]The lack of pass-through on wages for younger workers is consistent with the findings of Saez, Schoefer and Seim (2019) who document no difference in wages among the treated and untreated young workers in Sweden.

[7]In line with this prediction, we find more firm heterogeneity in responses among young workers who enter the labor market at an early age and so had more experience when they received the tax cut.

[8]In addition, wage setting constraints might be more important when workers age out from the subsidy. If the wages were fully passed through at younger ages, once workers age out of the subsidy they could experience a wage cut. Notice that for older people workers aging into the subsidy increasing wages above the age threshold is easier.

[9]Bozio, Breda and Grenet (2019) reconcile these seemingly conflicting results by the tax-benefit linkage explanation. In our case, tax-benefit linkages are not directly affected by the reform as the payroll tax did not affect workers' future benefits, which were calculated based on wages and not based on social security contributions, a common feature of payroll tax cut policies.

ments. Nevertheless, to date there is no conclusive evidence on whether such policies are successful. Some studies find non-negligible positive effects on employment (Kramarz and Philippon, 2001; Egebark and Kaunitz, 2018; Saez, Schoefer and Seim, 2019), while others find little evidence for employment effects (Boockmann, Zwick, Ammermüller and Maier, 2012; Huttunen, Pirttilä and Uusitalo, 2013). Our main contribution to this literature is that we focus on heterogeneity across firm types and offer a potential explanation for the inconsistencies found in the literature. Our heterogeneity results are not without antecedents in the literature, although our data and institutional setting make it possible to provide a more comprehensive overview on the differing impacts of payroll tax cuts by job and firm types. In line with our results, Albanese and Cockx (2019) find that a tax cut in Belgium targeting employees above age 58 increased employment at firms with high shares of low-wage workers, and at small firms.

Our paper also relates to the literature studying the impact of tax policies in the presence of search frictions (see e.g. Pissarides, 1985; Smith, 1994) or imperfect competition (see e.g. Berger, Herkenhoff and Mongey, 2022). Most of the literature makes theoretical arguments or presents calibrations to discuss the effect of tax policies on the allocation of labor and on the composition of jobs. For instance, Breda, Haywood and Wang (2019) study the heterogeneous impact of payroll taxes by calibrating a search and matching model in the French context. Here we instead provide direct empirical evidence on the heterogeneous impact of tax policies, which is a key prediction of these frameworks.

Finally, our paper is also related to the recent rent sharing literature that studies the impact of various firm-level and market-level shocks on wages and employment (see Card, Cardoso, Heining and Kline, 2018 and more recently Kline, Petkova, Williams and Zidar, 2019; Jäger, Schoefer, Young and Zweimüller, 2020; Garin and Silvério, 2022; Lamadon, Mogstad and Setzler, 2022). The documented interaction between worker and firm heterogeneity in pass-through rates has not been fully appreciated in this recent literature.

The remainder of this paper proceeds as follows. Section 2 introduces a search model with heterogeneous firms to illustrate the effect of payroll taxes in the presence of rents across firms. In Section 3, we provide background on the payroll tax reform we study and describe the Hungarian administrative data used for our empirical analysis. We present our employment results in Section 4 and wage results in Section 5. We discuss welfare effects in Section 6. In Section 7 we provide results for younger workers and women excluded from our main analyses. Section 8 concludes.

2 The Effect of Tax Cuts in Search Models

We study the impact of payroll taxes through the lens of a standard search and matching model. We introduce a tax cut in a framework with random search, heterogeneous firms and sequential bargaining on wages (Postel-Vinay and Robin, 2002). We study how the tax cut affects employment, wages, and the composition of job types in equilibrium. Our goal in this section is to illustrate that tax policies can have heterogeneous impact across different firms and not to model the specific tax policy implemented in Hungary. As a result, we abstract away from the age-specific nature of the tax cut. We also abstract away from worker heterogeneity and assume that job search is exogenous. These latter two assumptions can be relaxed without altering the basic predictions of the model (see e.g. Bagger and Lentz, 2019).

2.1 Setup

Firms are heterogeneous and characterized by productivity $y \in [y_{min}, y_{max}]$, with continuous cumulative distribution function $\Psi(\cdot)$. Workers are homogeneous. Workers are either unemployed or employed. If unemployed, they receive leisure of value b (with $b < y_{min}$) and search for jobs with probability one. If employed, they receive wage w, search for a new job with probability $s \in [0, 1]$ and can separate from their job exogenously with probability $\delta \in [0, 1]$.[10]

Firms advertise vacancies at an increasing and convex cost $\kappa(\cdot)$. Job market tightness is the ratio between total vacancies (v) and total search effort by the unemployed (u) and employed ($(1-\delta)(1-u)$):

$$\theta = \frac{v}{u + s(1-\delta)(1-u)}. \tag{1}$$

A searching worker locates an open vacancy with probability $\phi(\theta)$, increasing in θ. The probability for an open vacancy to meet a worker who is searching for jobs is $\phi(\theta)/\theta$, decreasing in θ.

Wage setting is based on sequential auction as in Postel-Vinay and Robin (2002). When an employed worker contacts an open vacancy, the prospective poacher and the incumbent employer observe each other's match qualities with the worker, and engage in Bertrand competition over contracts. The worker chooses the contract that delivers the larger value.

[10] We find that besides an increase in entry rate, some of the responses to payroll tax cuts come from a decrease in moving to unemployment. This could be explained within our framework by introducing advance notice layoffs or by introducing endogenous job separation by assuming that with δ probability there is a negative effect on productivity (instead of exogenous separation of the job match). Since our goal is to illustrate some key mechanisms and not match all patterns in the data, we abstract away from advance notice layoffs here.

Similarly to Postel-Vinay and Robin (2002) and Moscarini and Postel-Vinay (2018), we also assume that all the bargaining power is at the firms and so they are able to extract all rents from the workers.[11] Note, that even if workers are assumed to have no bargaining power, competition between firms for workers can still result in a very high labor share of firm revenues – this feature of the model is also pointed out by Dey and Flinn (2005). Details of the wage setting are provided in Appendix Section A.4.

2.2 Bellman Equations

The value of unemployment is the following:

$$V_u = b + \beta V_u, \tag{2}$$

where β is the discount factor. Notice that the probability of finding a job does not show up in the above equation, which comes from the assumption that firms have all the bargaining power. Even if the unemployed get a job offer, it will not make them better off. This will not be the case for employed workers as job offers will make them better off by the competition they induce between firms.

The joint value to the firm and the worker from a match is:

$$V(y,\tau) = y + \tau + \delta\beta V_u + (1-\delta)\beta V(y,\tau), \tag{3}$$

where τ is the lump-sum tax cut (we assume that $b + \tau < y_{min}$). Note that since we assume that all the bargaining power is at the firms, the joint value of the match goes to the firm.

Firms need to post vacancies to find workers. The value of posting vacancies will be the following:

$$V_v(y,\tau) = \max_{\nu} \Bigg\{ -\kappa(\nu) + \beta\nu\frac{\phi(\theta)}{\theta}\Bigg(P(u)\Big[V(y,\tau) - V_u\Big] + \\ + (1-P(u))\int_{y_{min}}^{y}\Big[V(y,\tau) - V(y',\tau)\Big]d\Gamma(y')\Bigg)\Bigg\} \tag{4}$$

where $-\kappa(\nu)$ is the cost of posting ν vacancies, which leads to $\nu\phi(\theta)/\theta$ chance to be matched to an applicant. In the value function above $P(u) = u/(u + (1-\delta)s(1-u))$ reflects the probability that a randomly drawn applicant is unemployed, which leads to the $V(y,\tau) - V_u$

[11] It is straightforward to introduce some bargaining power of the worker in the model. Nevertheless, empirical studies usually find that bargaining power is quite small and so abstracting away from that will not alter the conclusions made below.

profits, given that firms can extract all the surplus from the match. The chance that a randomly drawn applicant is employed is $1 - P(u)$ and the benefit of this from the firm's perspective depends on the previous employer of the applicant. If the applicant works at a more productive firm, then the firm cannot attract that worker and so there is no benefit from being matched to that applicant. That is why the integral goes only to y in the above formula. Nevertheless, if the firm meets with an applicant employed at a firm with lower productivity y', then the firm can poach that worker and acquire the difference between the new surplus ($V(y,\tau)$) and the surplus at the previous firm ($V(y',\tau)$). The chance that the firm meets with an employed worker at firm y' depends on the vacancy distribution function $\Gamma(y) = \int_{y_{min}}^{y} \nu(y',\tau)d\Psi(y')/(\int_{y_{min}}^{y_{max}} \nu(y',\tau)d\Psi(y'))$, where $\nu(y,\tau)$ is the optimal choice of vacancy of a firm y at tax cut level τ.

Plugging in $V(y,\tau)$ (equation (3)) and V_u (equation (2)) into equation (4), leads to:

$$V_v(y,\tau) = \max_{\nu} \Bigg\{ \underbrace{-\kappa(\nu)}_{\text{Cost of vacancy}} + \underbrace{\nu\frac{\phi(\theta)}{\theta}P(u)}_{\text{Probability of meeting unemployed}} \times \underbrace{\beta\left[\frac{y+\tau}{1-\beta+\delta\beta} - \frac{1-\delta\beta}{1-\beta+\delta\beta}\frac{b}{1-\beta}\right]}_{\text{Benefit of meeting with unemployed}} + \underbrace{\nu\frac{\phi(\theta)}{\theta}(1-P(u))}_{\text{Probability of meeting employed}} \times \underbrace{\beta\int_{y_{min}}^{y}\frac{y-y'}{1-\beta+\delta\beta}\Gamma(y')}_{\text{Benefit of meeting employed}} \Bigg\}. \quad (5)$$

This equation highlights the key trade-offs firms face when they decide about posting a vacancy. The first part reflects the cost of posting. The second part reflects the (expected) benefit of meeting an applicant who is unemployed, while the third part reflects the (expected) benefit of meeting with an applicant who is employed. The equation also highlights the key channels through which payroll taxes affect vacancy posting and employment. In particular, the tax cut only appears in the second part of this equation, which reflects the benefits of hiring from unemployment. At the same time, the tax cut has no impact on the third part of the value of vacancy posting, hiring from employment, as all firms receive the tax cut and the competition for workers will shift the surplus from the firms to the worker. Note that this shift in incidence of the policy will take place even if firms have all the bargaining power.

The equation, therefore, highlights that the tax cut increases the benefit of hiring from unemployment, while it has no effect on hiring from employment. It is worth highlighting that the stark difference between hiring from employment and unemployment is a consequence of the fact that all bargaining power is at the firms in our simple model. In practice, the unemployed might have some bargaining power and so they can acquire some of the surplus

from forming an employment relationship. Nevertheless, as long as workers do not have all the bargaining power, we will find that the tax cut benefits the firms if they hire from unemployment and the workers if they are poached from another firm.[12]

2.3 Equilibrium

Equilibrium is where firms optimally post vacancies up to the point where the marginal value of posting a vacancy equals its cost – they maximize equation (5). Furthermore, market tightness, θ, and the distribution of vacancies, $\Gamma(y)$, are consistent with firms' vacancy posting decisions. Finally, the steady-state equilibrium unemployment rate is:

$$u = \frac{\delta}{\delta + \phi(\theta)}. \tag{6}$$

In equilibrium more productive firms post more vacancies and as a result will employ more workers. This is because more productive firms earn more rent from hiring from unemployment and also are more likely to fill their vacancies when they meet with an employed applicant. Formally, this is a simple consequence of the value function shown in equation (5), where both the (expected) benefits of meeting with an unemployed (second part) and with an employed applicant (third part) are strictly increasing in productivity (y).

We derive the formula for the equilibrium wage in Appendix A.4. Assuming constant relative risk aversion (CRRA) utility function with rate of relative risk aversion ζ ($0 \leq \zeta < 1$), we can derive the wage at firm y' of an individual arriving from firm y, following Postel-Vinay and Robin (2002):

$$\ln \omega(y, y', \tau) = \frac{1}{1-\zeta} \ln \left[(y+\tau)^{1-\zeta} - \frac{(1-\zeta) s \phi(\theta)}{\frac{1-\beta}{\beta} + \delta} \int_y^{y'} (1 - \Gamma(x))(x+\tau)^{-\zeta} dx \right]. \tag{7}$$

The wage of workers whose wage is the first salary after unemployment is:

$$\ln \omega_u(y, \tau) = \frac{1}{1-\zeta} \ln \left[b^{1-\zeta} - \frac{(1-\zeta) s \phi(\theta)}{\frac{1-\beta}{\beta} + \delta} \int_{y_{min}}^{y} (1 - \Gamma(x))(x+\tau)^{-\zeta} dx \right]. \tag{8}$$

In equations (7) and (8), the first term in the brackets captures the maximum wage the

[12] In our model, following the search and matching literature, we assumed that unemployment benefit, b is unaffected by the previous wage (see e.g. Postel-Vinay and Robin, 2002; Bagger and Lentz, 2019). In practice, the unemployment benefit might reflect previous wages. Still, as long as the replacement rate of the unemployment benefit is less than 100%, firms hiring from unemployment will be able to capture some of the tax cut. In Hungary, the replacement rate of the unemployment benefit is around 50% and so the pass-through of earlier wages to the unemployment benefit will only be partial. Since our primary goal is illustration, we assume in our model that the unemployment benefit is fixed.

type-y firm could pay $(y + \tau)$ or the unemployment benefit (b). The second terms (the terms with the integral) capture the option value of working at the more productive firm. Intuitively, workers accept lower wages in exchange for the increased chances of higher wages in the future (Postel-Vinay and Robin, 2002). This option value increases with the relative productivity of the new employer, the search probability (s), the job finding rate $(\phi(\theta))$, the discount factor (β), and decreases with the rate of relative risk aversion (ζ), the job loss rate (δ) and the tax cut (τ).

2.4 Effects of the Tax Cut

We now study the effect of changing the tax cut. We describe what happens to the steady-state equilibrium when we raise the tax cut amount. Here we focus on the intuition and leave further details and proofs to Appendix A. We also quantify the effect of a tax cut that is 6% of the average wage in the economy—similar-sized to the tax cut that was instituted in Hungary—to highlight the effect of the policy on employment and wages.

Since the tax cut increases the value of posting vacancies (see equation (5)), firms will post more vacancies, which leads to tighter labor markets (θ) and lower equilibrium unemployment rate u. Furthermore, the employment and wage impacts of the tax cut vary across firm types. As we discussed before, firms get the surplus from the tax cut if they hire from unemployment, but competition between firms implies that the tax cut will benefit the workers if they are poached or if they receive an offer from another firm. Since low-productivity firms tend to hire from unemployment, they will benefit disproportionately more from the tax cut. This is because for them the value of posting a vacancy shown in equation (5) is dominated by the part coming from the benefit of meeting with an unemployed worker.

Nevertheless, the lower equilibrium unemployment rate implies that it is going to be less likely that a low-productivity firm will meet an unemployed individual as $P(u)$ falls. This dampens the vacancy posting of low-productivity firms though this effect will be small in practice whenever unemployment does not change radically. We underscore this intuition by quantifying the impact of a tax cut that is 6% of the average wage in the economy. We apply parameter values and functional form assumptions usually applied in the literature (we provide more details in Appendix A.6). The results are summarized in Panel (a) of Figure 1, which shows the percent change in employment at firms with below- and above-median productivity. In line with the intuition described above, we find that employment increases by 3.7% at the low-productivity firms, and by 0.8% at the high-productivity ones.

We also quantify the effect on wages in Panel (b) of Figure 1. Since in our main empirical exercise we study the change in wages for workers who had a job in the previous year, we study

here the change in wages for these incumbent workers.[13] We expect that wages will increase less at low-productivity firms, which mainly employ workers who came from unemployment and without any outside offer.[14] At the same time, most workers at high-productivity firms are poached from another firm or have received an offer from another firm, but decided to stay. These workers can use the tax cut as the threat point when bargaining, which drives up their wages. In line with this intuition, we find that wages increase by around 0.8% at low-productivity firms, which is close to a zero pass-through rate, while wages increase by around 2.9% at high-productivity firms. This latter reflects a 48% pass-through rate on average: workers at high-productivity firms get around 48% of the tax cut.

To sum up, the model predicts interesting heterogeneity in the incidence of the tax cut across firm types. The tax cut benefits low-productivity firms and workers who are employed at high-productivity firms. As a result, the tax cut affects the composition of jobs in the economy (as more low-productivity jobs are created) and benefits workers at better firms disproportionately. In the next section we turn to testing these predictions. It is worth emphasizing that our illustrative model is only one way to generate the observed heterogeneity in data. In alternative models, firm-level rents generated by asymmetric information (see e.g. Shapiro and Stiglitz, 1984) or by imperfect competition on the labor market (see e.g. Bhaskar, Manning and To, 2002; Manning, 2013; Berger, Herkenhoff and Mongey, 2022) could also be potential sources of heterogeneity. Our aim is not testing these alternative models of the labor market, but to document the empirical relevance of the heterogeneous incidence of payroll taxes and its potential impact on the composition of jobs.

3 Background and Data

3.1 Background

We study the impact of a large age-specific payroll tax cut instituted in Hungary in 2013. Before 2013, employers paid 28.5% of wages in social security contributions. In 2013, the government decreased the social security contributions of employers by around 14,500 Hungarian Forints (HUF, $66) per month for every employee older than 55. The average monthly salary net of employer payroll tax but before income tax and employee social security contri-

[13] More precisely, incumbent workers are those workers who are not newly hired from unemployment in this period. Incumbents include workers who worked at their current firm in the previous period and also those who worked at another firm in the previous period, but were poached in this period. The model predicts that workers who were hired from unemployment should experience a small increase in their wages with limited heterogeneity.

[14] If they had an outside offer, that offer would have likely come from a more productive firm and so they would have been poached by that firm.

butions was HUF 230,700 ($1,045) (Hungarian Central Statistical Office, 2022) so the payroll tax cut was 6.3% of the average salary.[15] The cut applied to both new and ongoing private sector jobs. Workers in the public sector and the self-employed were not eligible for the cut.

Besides workers aged over 55, workers under the age of 25 were also eligible for the tax cut. We discuss the impact of the policy on them in Section 7.2. Furthermore, workers in elementary occupations received the tax cut independently of their age.[16] In our primary analysis we include workers in elementary occupations, but our results are robust to the exclusion of those workers from the definition of private sector employment (see Appendix Table B4).

Figure 2 depicts the average effective payroll tax rate paid by employers by employee age before and after the payroll tax cut was implemented. It shows the discontinuity at age 55 after the policy took effect (in gray) compared to the constant rate of 28.5% before (in black). After the policy took effect the average tax rate is lower than 28.5% (rate without cut) at all ages due to the fact that workers in elementary occupations could get the tax cut independently of age. Furthermore, there is a drop from 26.3% to 20% or by about 6.3 percentage points from age 54 to 55. It is worth highlighting that such a drop in the tax rate does not create a discontinuity in hiring incentives at age 55. From the firm's perspective, hiring someone one day short of age 55 is almost the same as hiring someone at exactly age 55 as the difference is simply the one day for which higher taxes need to be paid, while once age 55 is reached, the same amount of tax cut is received. That is why we apply a difference-in-differences empirical strategy described in detail in Section 4, instead of a regression discontinuity strategy.

The reform only affected the social security contributions paid by employers, while the part paid by the employees was unaffected. Employees before and after the reform paid a 16% flat-rate tax and employee social security contributions of 18.5%.[17] Furthermore, the reform did not affect the link between social security contributions and future benefits (such as pensions) as those are calculated based on net wages and not based on contributions to the social security funds.

[15]The exact rules were the following. The social security contribution paid by employers was decreased from 28.5% to 14%, but the total amount of the tax cut was capped at HUF 14,500. As the minimum wage in 2013 was HUF 98,000 ($444), almost everybody hit the cap. For the few workers who earned exactly the minimum wage at HUF 98,000 in 2013, the tax cut was HUF 14,250. In 2014, the minimum wage was raised to HUF 101,500 ($460).

[16]Long-term unemployed re-entering the labor market, people returning to work after child-care leave, or younger workers entering the labor market received the tax benefit for 2 years independently of their age. The prevalence of these other beneficiary groups is close to zero for those aged 52-57.

[17]The tax wedge on labor is quite high in Hungary. Adding social security contributions and the income tax the average tax wedge was close to 50% in this period, which is much higher than the OECD average of 35.5% (OECD, 2022*a*).

The tax cut was first publicly discussed in the Parliament on July 2, 2012, shortly after it was announced. The legislation was passed on October 15, 2012, and the tax change was effective from January 1, 2013. Due to the relatively short period of time between the announcement and enactment of the reform, anticipatory effects appearing before the implementation of the tax cut are likely to be negligible and we find no evidence of such effects in our empirical analysis.

In the main analysis, we study the impact of the reform among older men between 2010 and 2015. Throughout this period there were no other major labor market policy changes that affected older men. We focus on men to make sure that results are not driven by early retirement policy changes for women instituted in 2011.[18] Nevertheless, we find very similar results for women in Section 7.1 suggesting that our findings are not gender specific.

Around this period the overall employment rate in Hungary was 64%, slightly below the OECD average (66%). The employment rate of older people (age 55-64) was only 46%, substantially below the OECD average (58%). The unemployment rate decreased steadily between 2012 and 2015, which reflected a substitution of welfare programs with a public work scheme (Cseres-Gergely and Molnár, 2015). At the same time, employment in the private sector was relatively stable: the prime-age population share employed in the private sector increased slightly from 38% to 39% between 2012 and 2015. Still, to make sure our results are not driven by the improvement of labor market conditions, we show robustness to restricting the sample to local labor markets where the share of employment in the private sector among the prime-age population was stable throughout the whole period.

Since our primary focus is on the heterogeneous impact of the policy, it is worth discussing whether different types of firms face different labor market institutions. In Hungary, it is relatively easy to hire or dismiss workers (Tonin, 2009). Wage bargaining takes place mostly at the individual level. The rare collective wage bargaining is based on firm-level agreements and the coverage of these policies is low. The unionization rate was around 10% in this period, one of the lowest in the OECD (Hungarian Central Statistical Office, 2016; Borbély and Neumann, 2019; OECD, 2022*b*). The weak labor market institutions and the lack of any size-specific regulations imply that firms with different size or productivity face similar institutional constraints in setting wages and employment.

3.2 Data

We use linked employer-employee administrative data from Hungary covering years 2010–2015 on a random 50% sample of the 2003 population. Since our sample is drawn from the whole

[18] A new pension policy for women was introduced in 2011, which granted an early retirement option for women with 40 years of work credits, regardless of age.

population (and not just those who have a job) our data can be used to study changes in employment in response to the policy.

We also observe in the data the employer of the worker (or self-employment). For employers with double-entry bookkeeping we can merge balance sheet information from the Hungarian tax authority.[19] We restrict our main analysis to men because there was a change in retirement rules affecting women throughout the period studied here. We document women's employment responses in Section 7.1.

An individual is defined to be a private sector employee if she is employed on the 15th of a month at a private sector firm with double-entry bookkeeping.[20] We include part-time workers, but adjust the employment indicator by working hours (e.g. working 20 hours per week is considered as 0.5 employment). Our main outcome in the wage regression is the (full-time equivalent) net wage as of May of each year. We follow Saez, Schoefer and Seim (2019) and define net wage (sometimes abbreviated to wage) as wage earnings net of employer payroll tax. This net wage measure is calculated before income tax and employee social security contributions are deducted and includes base payment, bonuses and overtime pay.

Appendix Table B1 provides a comparison of employment statistics based on the administrative data we use with official statistics which are based on the Hungarian Labor Force Survey. These statistics are very similar, indicating the reliability of the employment indicators we define based on the administrative data.

We generate firm-specific indicators that we use in the heterogeneity analyses. Our baseline indicator of firm quality is the value added-based total factor productivity (TFP).[21] As another indicator of firm quality, we perform an Abowd, Kramarz, Margolis (AKM) style decomposition of wages (Abowd, Kramarz and Margolis, 1999) and calculate firm wage

[19]The monthly labor force status and wage indicators originate from the Hungarian Social Security Administration. The demographic indicators originate from the National Health Insurance Fund Administration of Hungary. The firm-specific indicators originate from the National Tax and Customs Administration of Hungary.

[20]We focus on firms with double-entry bookkeeping as most quality measures (e.g. TFP) are only available for them. In addition to that we exclude from the benchmark analysis seven firms which have more than 10,000 workers—very large and unique firms in the Hungarian context—to avoid outliers driving the results. Appendix Table B2 shows that our results are robust to the inclusion of the largest firms and single-entry bookkeeping firms—the estimated employment effects and heterogeneity results by firm quality are stronger under the extended definition.

[21]We use the *prodest* Stata module of Rovigatti and Mollisi (2020) and apply the estimation procedure of Wooldridge (2009). We regress the logarithm of value added (gross revenue minus the cost of goods sold) on year effects, the logarithm of firm size (variable input) and the logarithm of subscribed capital (state variable), while using material and service costs as proxies for unobserved productivity. The TFP is the residual estimated from this regression. Finally, we take the firm-specific average of the TFP indicator over 2010-2015.

premia.[22] We also use firm-level average wage (discounted and averaged over 2010-2015) as a quality indicator. Finally, we also classify firms as foreign-owned if foreign ownership is above 50%. In the Hungarian context foreign ownership is a strong predictor of firm productivity, export orientation, and quality (Kaminski, 1999).

In our main empirical analysis, we restrict the sample to men and use workers aged between 52-57 (with workers aged 52-54 serving as the control group and workers aged 55-57 comprising the treatment group). We do not study the employment change of workers older than age 58 as those workers could retire before the reform, but not after the policy change due to the elimination of some early retirement options.[23] We restrict our sample to the non-retired population to ensure that the estimated employment effects are not driven by the aging-out of already retired individuals from our sample. Appendix Table B5 shows that the estimated employment change and the heterogeneity patterns remain similar if we include retired individuals in the sample. For the workers in our sample, the retirement age was 65 (and 64 for some older cohorts). We find no evidence that the cohorts with slightly older normal retirement age behave differently at age 52-57 so our main estimates are not driven by anticipation effects stemming from extending the retirement age.

Table 1 provides summary statistics on our data. The top panel suggests that the treatment and the control age groups are remarkably similar in terms of employment, wages and share of white collar jobs. The middle panel summarizes the distribution of treatment and control workers across high- and low-productivity firms. For each measure (except for foreign ownership), we divide firms into above-median and below-median groups, taking the median based on all private sector workers, irrespective of their age. The share of workers at high-productivity firms is very similar in the treatment and control groups. Finally, in the bottom panel we examine the industry composition of treatment and control workers. Again, we find very small differences suggesting that the treatment and the control groups are similar.

[22] To estimate the firm wage premia, we use all sample years of the linked employer-employee administrative data. We regress wages on individual and firm fixed effects, controlling for year fixed effects, age squared, age cubed, and firm size.

[23] The earliest age to retire was age 58 until 2011, but that possibility was abolished then. To retire at age 58, someone needed to have a long term employment relationship and at least 37 years of employment history. Note that all workers aged between 52 and 57 between 2012 and 2015 (our main estimation sample) could only retire at the normal retirement age, and so workers in our sample were not affected directly or indirectly through anticipation effects in our main sample. Nevertheless, workers who turned 58 before 2012 will have lower employment rate and higher retirement rate than workers who turned 58 after 2012. By restricting the treatment ages to 55-57 in our analysis we make sure our employment changes are not affected by the change in retirement rules instituted one year before our policy change.

4 Effect on Employment

4.1 Descriptive Evidence

Figure 3 shows the share of men working at private sector companies by age before and after the payroll tax cut was introduced in 2013. Panel (a) shows raw employment rates by age before (year 2012, in black) and after (years 2013-2015, in gray) the policy took effect. The figure highlights that employment rates in the private sector gradually decline with age from 41% to 33%. Furthermore, employment rates were similar in 2012 and 2013-2015 for workers younger than 55, which highlights that private sector employment was relatively stable in this period.[24] Finally, there is a clear divergence for workers 55 and older who are affected by the tax cut.

Panel (b) shows the change in employment at private sector companies for men at each age—the difference between the 2012 (black line) and the 2013-2015 employment rate (grey line) shown in Panel (a). In the spirit of our difference-in-differences strategy, we subtracted the average employment change between 2012 and 2013-2015 for the workers between ages 41 and 54. The figure highlights that the employment change was significantly higher above the age 55 cutoff: a 55-year-old worker was 1 percentage point more likely to be employed shortly after the policy was introduced.

4.2 Main Results

To study the impact of the payroll tax cut in a difference-in-differences framework, we focus on workers aged 55-57 as our treatment group and workers aged 52-54 as our control group. As we discussed above, the labor market characteristics and the employment composition across firm types and industries are quite comparable across the two groups. We also explore below the sensitivity of the estimates to changing this treatment/control definition.

To study the impact of the tax cut on employment, we estimate the following equation

$$Emp_{it} = \theta_t + \sum_{k=52}^{k=57} \alpha_k \mathbb{I}[age_{it} = k] + \beta \mathbb{I}[t \geq t_{reform}] \cdot \mathbb{I}[age_{it} \geq 55] + \varepsilon_{it}, \tag{9}$$

where Emp_{it} is measure private sector employment of individual i in month t, θ_t are monthly time effects, $\mathbb{I}[age_{it} = k]$ are age effects, $\mathbb{I}[age_{it} \geq 55]$ is a dummy for the eligibility cut-off, which is age 55 in our context, and $\mathbb{I}[t \geq t_{reform}]$ is the post reform dummy, where t_{reform} is January 2013. In the baseline specification the t index runs from January 2012 to December

[24] The average private sector employment rate between ages 41 and 54 in 2013-2015 is 38.4, while it is 38.3 in 2012. Therefore, the employment rate in the untreated population is almost the same pre and post policy.

2015 and we restrict the sample to individuals who are between 52 and 57 years old. We cluster the standard errors at the age×period level.

Our coefficient of interest is the β term which captures the differential change in private sector employment between the periods before and after the tax cut for treated workers relative to control workers. Panel A of Table 2 reports the baseline estimates on β—the difference-in-differences estimate of the impact of the tax cut on employment. We measure private sector employment (Emp_{it}) by including part time jobs adjusted for working hours (e.g. working 20 hours per week is considered as 0.5 employment).[25] Column (1) shows that private sector employment increased by 0.53 percentage points from a baseline of 33% or by 1.59 percent as a result of the payroll tax cut. In Table 2, we also calculate the implied labor demand elasticity. The effective tax cut was 6.6 percentage points (5.27% decrease in labor costs), which implies that the increase in employment corresponds to an employment elasticity of -0.30 (s.e. 0.03). Appendix Table B3 shows that these results are virtually identical if instead of adjusting employment for working hours, we use a binary employment indicator.

Our elasticity estimate for overall employment is close to what others have found in the literature. For instance, Laun (2017) finds an employment elasticity of -0.22 for older workers in Sweden, while Huttunen, Pirttilä and Uusitalo (2013) find an elasticity of -0.1 in Finland. For younger workers, Saez, Schoefer and Seim (2019) find an employment elasticity of -0.23 in Sweden, while Egebark and Kaunitz (2018) estimate an elasticity of -0.3 in response to the young worker tax cut instituted during the Great Recession in Sweden.

Motivated by the prediction of the standard search and matching framework presented in Section 2, we also investigate whether responses to the policy differ by firm type. Columns (2) and (3) of Table 2 summarize the key results. We use regression equation (9) with an outcome variable of being employed by a firm with below (column 2) or above (column 3) median total factor productivity. The results show that virtually all the employment increase comes from low-productivity firms, while the employment change is close to zero at high-productivity ones.

Table 2 also highlights that differences in employment responses cannot be fully explained by the differential impact of the policy on the change in labor cost. Since the amount of tax cut was the same for every worker, the proportional change in labor cost is slightly lower at high-productivity firms, which tend to pay more to their workers. Indeed, we calculate that the labor cost decreases more at low-TFP firms than at high-TFP firms (6.02% vs. 4.45%). Still, the change in labor cost was considerable even at high-TFP firms, with an 4.45 percent

[25]The share of part-time jobs was very low in this period. Among men, around 90% of all private sector jobs were full-time.

decline in labor cost. As a result, the employment elasticity with respect to cost of labor is precisely estimated for the high-TFP firms as well. The estimated elasticity is -0.53 at low-productivity firms and 0.01 at high-productivity ones, and the difference in responses to the tax cut between the two firm types are both statistically and economically significant.

4.3 Robustness and Credibility Checks

Parallel trends. The standard identifying assumption in difference-in-differences regressions is that employment in the treatment and control groups would have evolved similarly in absence of the policy change. While this assumption cannot be tested directly, we can study whether the assumption holds pre-policy. To do that we estimate the evolution of the difference between the treatment and control groups over time using the following regression:

$$Emp_{it} = \theta_t + \sum_{k=52}^{k=57} \alpha_k \mathbb{I}[age_{it} = k] + \sum_{\substack{h=2010 \\ h \neq 2012}}^{h=2015} \beta_h \mathbb{I}[Year_t = h] \cdot \mathbb{I}[age_{it} \geq 55] + \varepsilon_{it}, \qquad (10)$$

where the variable definitions are the same as for equation (9). In this regression the β_h coefficients show the difference between treatment and control workers in year h and we report those in Figure 4. The red squares show the change in employment at high-TFP firms, where we use employment at above-median TFP firms as the dependent variable. The blue diamonds show the estimates at low-TFP firms, where we use employment at below-median TFP firms as the dependent variable. The figure highlights that prior to the introduction of the policy, the employment rates of treated and control workers evolved similarly both at high- and low-TFP firms, suggesting that the control workers are likely a good counterfactual for the treatment workers. At low-TFP firms, employment among treatment workers increased relative to the control group exactly when the reform was introduced in 2013. The impact on employment was around 0.5-0.6 percentage point over years 2013-2015 at low-productivity firms. At the same time, employment at high-productivity firms stayed similar among control and treatment workers.

SUTVA assumption and changing the treatment and control definitions. Another key assumption in difference-in-differences style regressions is that the treatment does not affect the control group—the so called stable unit treatment value assumption. In our case, this does not necessarily hold as those close to the age threshold age into the treatment, which could affect their labor market opportunities. Nevertheless, differential treatment effects still hold even if the differences disappear as we go closer to the age 55 cut-off.[26] This spillover

[26]This is why we do not apply a regression discontinuity approach here.

effect of the treatment to the control group should be less important as we move further away from the age 55 cut-off. Indeed, Panel (b) of Figure 3 shows that relative to the average employment rate between ages 41 and 54, we estimate a slightly larger treatment effect, than relative to the average employment rate of those closer to the age cut-off. In Figure 5 we further explore the robustness of our employment results to alternative definitions of the treatment and control age groups. Panel (a) shows the estimates for overall employment, while Panel (b) shows the estimates for employment at low- and high-TFP firms separately. The first three estimates from the left keep the benchmark treatment definition (age 55-57), but use control groups farther away from the age 55 cut-off, defining as control group first those who are between 52 and 53 years old and then only 52-years-old individuals. Both the overall employment effect and the estimated difference between the low- and high-TFP firms are similar in these specifications. Next, we show estimates when the treatment group is narrowed, while keeping constant the benchmark control definition. We show estimates first when the treatment group covers only those between 56 and 57 and then when it covers only 57-year-old individuals. The estimated effects are virtually identical in all these specifications suggesting that our estimates are not sensitive to changing the age window in the estimation.

Effects across the wage distribution. We estimate the change in employment throughout the entire distribution of wages, similarly to the approach of Cengiz, Dube, Lindner and Zipperer (2019). Since the payroll tax cut was lump-sum, we expect that employment would be mainly affected at the bottom of the wage distribution, while the employment effect would be close to zero in the upper part of the wage distribution, where the lump-sum tax cut only introduces a small (relative) change in labor cost. Panel (a) of Figure 6 shows the change in employment at all firms. The estimates show that the largest employment effects arise for workers earning between 90% and 150% of the minimum wage, but that there are also substantial effects for workers between 150% and 300% of the minimum wage. At the same time, in line with the lump-sum nature of the tax cut, we do not find any change in employment above 300% of the minimum wage. Panel (b) of Figure 6 shows the employment changes separately for low- and high-productivity firms. The figure demonstrates that most employment changes occurred at low-TFP firms (blue diamonds). At the same time, the changes in employment at high-TFP firms (red squares) are very small and close to zero throughout the entire wage distribution. This latter partly reflects that there are fewer low-wage jobs at high-TFP firms (see Appendix Figure B1 on the density of jobs in each wage category). Nevertheless, even if we consider the wage category between 150% and 300% of the minimum wage, where there is a high density of jobs at both low- and high-TFP firms we find clear differences in the employment changes: while the change in employment is

substantial and statistically significant at low-TFP firms, the change in employment is close to zero at high-TFP firms.

Placebo groups unaffected by the tax cut. As we mentioned in Section 3, the reform only affected private sector employees, while the self-employed and workers in the public sector were unaffected by the tax cut. Employment in these groups therefore should not be affected by the policy change. Furthermore, it is also possible that changes in private sector employment simply reflect switching from the public sector or from self-employment. Table 3 explores the source of the private sector employment increase by estimating our main regression equation (9) with mutually exclusive outcome variables: being employed in the private sector (including employment at single-entry bookkeeping firms and at firms with more than 10,000 workers, thus using a broader private sector employment definition than the definition used throughout the rest of the paper), being self-employed, working in the public sector, or being inactive/unemployed. Since these outcome variables are collectively exhaustive, the increase in one outcome must reflect a decline in other ones. Table 3 shows that the tax cut had a positive effect on employment at private sector firms – due to the inclusion of the smallest (single-entry bookkeeping) firms, the estimated effect is stronger than the baseline results (see Appendix Table B2 for a comparison of the definitions). Table 3 also shows that there is a slight reduction in the likelihood of being self-employed but the estimated change is an order of magnitude smaller than the employment changes we found for private sector employees. As a result, the switch from self-employment to private sector employment can explain at most 15% of the total increase in private sector employment (considering all categories of private sector firms). Furthermore, the slight negative impact on self-employment was fully offset by the slight increase in public sector jobs. As a result, the increase in the share of private sector employees mainly comes from a decline in unemployment and inactivity. Appendix Figure B2 corroborates these findings by replicating the descriptive evidence on changes in private sector jobs (Panel (b) of Figure 3) for public sector job (Panel (a)) and for the self-employed (Panel (b)). The change in employment in these two placebo groups is very small, suggesting that the increase in private sector employment in the treated age groups reflects the impact of the tax cut and not something else.

Effect by various firm quality measures. So far, we have focused on the heterogeneous effect of the policy along one dimension of firm quality: firms' total factor productivity. Nevertheless, there are other potential ways to measure firm quality. For instance, our theoretical framework presented in Section 2 suggests that the heterogeneous incidence should emerge if we consider high paying firms. In Panel (a) of Figure 7, we replicate the heterogeneity

analysis in the employment effects with other firm quality measures (for short-run effects see Appendix Table B6).

Foreign-owned firms are the most productive firms that are usually well integrated into the world economy. Those firms are offering the highest paying, highest quality jobs in the Hungarian context. The estimated employment change at those firms is close to zero and statistically insignificant. At the same time, domestic firms, which are usually less efficient, responded to the policy by creating many new jobs. A similar pattern can be observed when we measure firm-quality using average wages or AKM firm effects. Low-paying firms create many new jobs, changing the composition of jobs in the economy.

Overall these estimates highlight that the composition of jobs changes in response to the tax cut, as low-quality firms will create more jobs than high-quality ones. To make sure that the results are not driven by the endogenous response of total factor productivity and other quality measures to the reform, we replicate the heterogeneous effects using only pre-reform years to define the firm quality indicators. Our results are almost the same using the pre-reform definitions of firm quality measures (Appendix Table B7).

4.4 Worker Type vs. Firm Type Heterogeneity

So far, we have focused on the heterogeneous responses to the policy by firm type. Nevertheless, the differential responses by firm type might simply reflect that different types of workers sort to different types of firms. For instance, high-skilled workers might have more bargaining power and they also tend to work at high-TFP firms. To explore the empirical relevance of this interpretation of our main findings, we estimate the employment effects and firm heterogeneity for workers with similar skills.

In Table 4 we replicate the main analysis for various skill groups. Panel A shows the estimates when we examine the change in employment at jobs earning at most 1.5 times the minimum wage and for jobs earning above that. This is a similar exercise as in Figure 6 where we studied the employment effects throughout the wage distribution. The workers earning at most 1.5 times the minimum wage are predominantly low skilled ones and we see that their employment also increases slightly at high-TFP firms. When we focus on higher skilled workers with wages above 1.5 times above the minimum wage, we still see a clear heterogeneity in the data. Almost all the employment changes come from low-TFP firms, while high-TFP firms do not hire more even if they employ many workers in that wage category. These results suggest that the heterogeneous employment effect by firm productivity is not driven by the different earnings composition of jobs by firm productivity.

Panel B shows the main estimates by worker heterogeneity when we proxy workers' skill

with occupation. We calculate the change in employment separately for low-paid and high-paid occupations. Low-paid occupations are those that pay below the median on average and high-paid occupations are those that pay above the median on average. The table shows that employment increased by a similar amount in both low-paid (0.28 percentage points) and high-paid (0.24 percentage points) occupations. Furthermore, there is clear heterogeneity within both low-paid and high-paid occupations: virtually all the employment change comes from low-TFP firms. Columns (5) and (6) also highlight that the employment elasticity is similar in low-paid and high-paid occupations. At low-TFP firms it is close to -0.50, while at high-TFP firms it is close to zero within both occupation groups.

Finally, in Panel C we study worker heterogeneity by education. Since we do not observe education directly, we again rely on occupation information in our data. First, we use the Hungarian Labor Force Survey[27] that has detailed information on education and occupation for the same individuals for a large sample of workers. We calculate the mode of the education level for each four-digit occupation. Then we assess the employment change by the modal education-level in each occupation.

The table shows that the employment increase mainly comes from the lowest-skilled workers with primary or lower-secondary education. There is also a slight increase in employment for workers with tertiary education and no change workers with upper-secondary education. When we look at employment changes within an education group, we find clear indication for firm heterogeneity in all cases. Employment at low-TFP firms increased within every group and the elasticities vary between -0.22 and -0.69 (see column 5). These elasticities are statistically significant in all cases at the 5% level. At the same time, there is no evidence for significant employment change at high-TFP firms in any education group. The employment change is close to zero in all cases and the elasticities are statistically insignificant at the conventional levels. Overall, these findings highlight that the firm heterogeneity is present even if we focus on a group of workers with the same skill level and so our main results reflect firm heterogeneity and not only worker heterogeneity.

4.5 Effect on Worker Transitions and Firm Dynamics

The estimated employment change can come from two sources: (1) workers who have been employed previously and keep their jobs at higher rates (incumbents) or (2) workers who were unemployed/inactive before and become employed (new entrants). Panel A of Table 5 decomposes our main employment effect into these two groups. We define incumbent workers as those who had a job in the previous 12 months (between $t-1$ and $t-13$) and

[27]The Hungarian Labor Force Survey (Hungarian LFS) is very similar to the Current Population Survey in the United States.

new entrants as those who had at least one month without a job in that period. Then we estimate regression equation (9) using private sector employment as the outcome separately for incumbents and new entrants.

Panel A of Table 5 summarizes the key findings. Employment for new entrants increases by around 0.15 percentage point, which is around 28% of the overall 0.53 percentage point increase reported in Panel A of Table 2. This is nevertheless a quite substantial, 3.5% increase relative to baseline population share (4.3%) of new entrants. Employment for incumbents increases by 0.38 percentage point, which is 72% of the overall 0.53 percentage point increase in employment. This is a 1.3% increase relative to the baseline share (29%) of incumbents. These results highlight that the tax cut affected labor market transitions by inducing both higher labor market (re)entry rates and lower exit rates among workers in the treatment age group.[28]

Besides labor market dynamics, we can also study the potential change in firm dynamics. Panel B of Table 5 shows the decomposition of the total change in employment into newly entering firms (did not exist in the previous calendar years) and firms that existed before. We find that almost all the employment creation comes from firms that existed before, suggesting that no new firms were set up in response to the tax cut. Panel C corroborates these findings by showing that employment mainly increased at firms that existed before 2012, while the change in employment at newly created firms is negligible.

4.6 Labor Market Institutions and the Minimum Wage

As we noted before in Section 3.1, unions are weak in Hungary and central bargaining of wages is almost non-existent. As a result, larger firms do not usually face more organized workforces with more institutional protections. Still to make sure that our results are not simply driven by large firms, we examine heterogeneity by firm size in Appendix Table B8. We divide firms into two size categories, using the definitions of OECD (2022*c*): micro and small firms (1 to 49 employees) and medium-sized and large firms (50 or more employees). More refined categorization is hindered by the fact that the vast majority of the smallest

[28] Our theoretical model presented in Section 2 predicts an increase in re-entry rate as a consequence of more vacancy posting, while the job destruction rate is kept exogenous and constant. Under these assumptions the change the employment of incumbents could be explained by the presence of advance notice lay-off, which is quite common in Hungary for the elderly. When a worker is notified in advance, she might move to a new job without becoming unemployed, and so that transition will look like a job-to-job transition in the data, even if it would be someone entering from unemployment from the model's perspective. An alternative way to incorporate change in the employment of incumbents would be endogenizing job destruction in the model. While this latter approach might be important for calibrating the model to the data, we can still illustrate the key channels through which payroll tax cuts affect employment and wages in search models without that feature.

(micro) firms have below-median TFP and the vast majority of large firms have above-median TFP. We find that employment at low-productivity firms increases in both firm size categories, while among high-productivity firms there is no consistent employment effect in either firm size category.

We also discuss the potential impact of minimum wages on our results (Harasztosi and Lindner, 2019; Bíró, Prinz and Sándor, 2022). In the presence of binding minimum wages, the tax cut could make some jobs viable, which could explain why job creation takes place disproportionately at low-productivity firms. That might play some role: as we saw on Figure 6, some jobs were created around the minimum wage in response to the tax cut. Nevertheless, there is also significant job creation substantially above the minimum wage at low-TFP firms, which means that our findings do not simply reflect the interaction of the minimum wage with the tax cut.

We also showed in Section 4.5 that firm dynamics and new firms entering after 2012 are not the major source of job creation (see Table 5) and around 78% of the jobs come from incumbent workers. This again suggests that the extra jobs are unlikely to simply reflect jobs that were not viable before.

4.7 The Role of the Economic Environment

As we discussed in Section 3.1, the Hungarian labor market was booming in this period. To understand the importance of local economic conditions, we study the impact of the policy across local labor markets in Appendix Table B10. The country consists of 197 districts. We first divide districts by unemployment rate in 2012 and study the impact separately in districts with above- and below-median unemployment rates in Panel A. The effect of the tax cut on employment is somewhat larger in regions with above-median unemployment rate, where the average unemployment rate was around 18.3%, than in regions with below-median unemployment rate, where the average unemployment rate was around 8.6% (0.65 percentage points vs. 0.55 percentage points). Nevertheless, the heterogeneity is very similar across firms, as almost all the employment change comes from low-TFP firms.

In addition, we also divide districts by the change in private sector employment rate in Panel B. In stable labor markets the change in private sector employment is less than 2 percentage points (in absolute value), while in improving labor markets the change is more than 2 percentage points. The change in employment and the heterogeneity pattern is very similar in booming and stable environments.[29] Overall, these findings suggest that local economic conditions are unlikely to play a major role in explaining our main findings.

[29]We do not have enough districts with substantial decline in labor market conditions and so we cannot study the impact of the tax cut in a recessionary environment.

Finally, Panel C shows that the employment effects and the heterogeneity patterns are similar in districts with below- and above-median share of individuals aged 55-57 (who form the treatment ages in our analysis).

4.8 Substitution

A common concern about targeted tax cuts is that firms may substitute treated workers for untreated ones. This substitution could bias our main estimates, if it leads to substantial change in employment in the control group. Nevertheless, as we discussed in Section 4.1, there is no indication of any significant change in employment in the data among individuals in the control group. The lack of large employment responses in the control group is not surprising given that only a low share of the workers are treated and so the substitution effect on untreated workers should be limited.[30]

A different concern from the policy maker's perspective could be that firms who hire more treated workers might decide to hire fewer prime age or other untreated workers. We directly test the empirical relevance of this concern by studying the firm-level relationship between hiring treated and untreated workers before and after the policy change in Appendix Figure B3. The figure shows the non-parametric relationship between (two-year) change in employment of treated workers and that of untreated ones (relative to the employment at baseline). We calculate the pre-policy relationship by studying the change between 2010 and 2012 (black dots and line) and the post-policy relationship between 2012 and 2014 (blue stars and line). We also calculate the no substitution counterfactual (red squares and line): how much the pre-policy relationship would change if firms increased their hiring of treated workers as we estimated in the benchmark analysis (Table 2), but did not decrease their hiring of untreated workers. This no substitution counterfactual is closely aligned with the post reform relationship, indicating that substitution from untreated workers is limited in our context.

[30]This argument is similar to the one made in Appendix Section B in Cengiz, Dube, Lindner and Zipperer (2019). Given that the share of treated workers in the aggregate production function is small, realistic values of labor-labor substitution put an upper bound on the size of employment changes of the untreated population.

5 Effect on Wages

5.1 Main Results

Motivated by the illustrative model predictions presented in Section 2, we study the impact of the tax cut on wages in this section. First, we study the impact on the wages of new entrants by estimating the following regression equation:

$$\ln w_{it} = \sum_{k=52}^{k=57} \alpha^k \mathbb{I}[age_{it} = k] + \theta \mathbb{I}[year_t \geq t_{reform}] + \beta \mathbb{I}[year_t \geq t_{reform}] \cdot \mathbb{I}[age_{it} \geq 55] + \varepsilon_{it} \tag{11}$$

where w_{it} is the net wage of individual i in May at year t. Note that for wages, we use annual data throughout this section as this is the level of observation available.[31] In our case, t_{reform} is 2013.

A key limitation of the regression equation above is that it considers the same proportional wage changes across the entire wage distribution. Nevertheless, given the lump-sum nature of the tax cut, we expect that the proportional increase in wages will be quite small for high wage earners and could be much larger for low wage earners. To take this into account, we assess the impact of the policy by the tax cut rate – the size of the payroll tax cut relative to the wage in the previous year, formally $TCR_{it-1} = 14,500/w_{it-1}$, where HUF 14,500 is the tax cut amount. This variable goes from 14.5% for low wage earners to zero for very high wage earners, and reflects the percent change in wages that would occur if all of the tax cut were passed through to the worker. Notice that the tax cut rate is calculated for both treated and control workers. For the latter, the tax cut rate reflects the size of the tax cut (relative to their income) that would have been received if the workers were treated.

Then we estimate the following regression:

$$\begin{aligned} \ln w_{it} = &\sum_{k=52}^{k=57} (\alpha_0^k + \alpha_1^k TCR_{it-1}) \mathbb{I}[age_{it} = k] + (\theta_0 + \theta_1 TCR_{it-1}) \mathbb{I}[year_t \geq t_{reform}] + \\ &+ (\beta_0 + \beta_1 TCR_{it-1}) \mathbb{I}[year_t \geq t_{reform}] \cdot \mathbb{I}[age_{it} \geq 55] + \varepsilon_{it} \end{aligned} \tag{12}$$

where we interact each term in regression equation (11) with the tax cut rate, TCR_{it-1}. To calculate TCR_{it-1}, we need to rely on the previous year's wage and so we can only estimate this regression for workers who worked in the previous year (incumbent workers).

[31] We only see annual income for employment relationships spanning the entire year. This is a common feature of administrative social security data (see e.g. German IAB data).

This is consistent with our model which predicts that the incidence of the policy would be heterogeneous among incumbent workers (who have a job offer and stay or are poached) but not among new entrants (who come from unemployment and have low bargaining power).

Furthermore, to make sure that our exposure measure TCR_{it-1} is not contaminated by the policy itself, we only use one post-policy year 2013 and one pre-policy year 2012 in the benchmark regression. Later we perform a robustness check where we define the tax cut rate based on wages two years before, formally $TCR_{it-2} = 14,500/w_{it-2}$, and then we use data from 2014 and 2012. In the benchmark specification we also focus on full-time, full-month workers, to minimize measurement error in wages, and present robustness checks which include part-time workers.

The results of the wage regressions are reported in Table 6. Column (1) estimates wage effects for new entrants using equation (11). The change in the wages of new entrants is economically small and statistically insignificant. This is in line with the prediction of the model that suggests that the effect of the policy on new entrants should be limited.

Table 6 also shows the estimates for the incumbent workers for whom we can calculate the tax cut rate. Column (2) suggests that the average impact of the tax cut on wages among incumbent workers is positive. The coefficient showing the treatment effect post policy in relation to the tax cut rate (β_1) is 0.22 (s.e. 0.09). This implies that a \$1 increase in the tax cut would result in a 22 cent increase in wages on average, or that average pass-through is 22% with firms capturing 78% of the tax cut on average.

We also examine heterogeneity in this treatment effect. We estimate the following equation, using the notation of equation (12):

$$\begin{aligned}\ln w_{it} = &\sum_{k=52}^{k=57}(\alpha_0^k + \alpha_1^k TCR_{it-1} + \alpha_2^k Q_{j(i,t)} + \alpha_3^k TCR_{it-1}Q_{j(i,t)})\mathbb{I}[age_{it} = k] + \\ &+ (\theta_0 + \theta_1 TCR_{it-1} + \theta_2 Q_{j(i,t)} + \theta_3 TCR_{it-1}Q_{j(i,t)})\mathbb{I}[year_t \geq t_{reform}] + \\ &+ (\beta_0 + \beta_1 TCR_{it-1} + \beta_2 Q_{j(i,t)} + \beta_3 TCR_{it-1}Q_{j(i,t)})\mathbb{I}[year_t \geq t_{reform}] \cdot \mathbb{I}[age_{it} \geq 55] + \varepsilon_{it},\end{aligned} \tag{13}$$

where we interact all coefficients in equation (12) with $Q_{j(i,t)}$, the productivity of firm j where individual i works at time t. To check that our estimates are not simply driven by transitioning to high-productivity firms, in Appendix Table B11 we show that the estimated treatment effects are robust to using the firm productivity in the previous year.

Column (3) of Table 6 shows the main estimates of treatment effect heterogeneity. The estimates show that the wage effects are driven by high-productivity firms. In high-

productivity firms, the pass-through rate is 60% (the sum of β_1 and β_3, which is 68% plus -8%) and statistically significant. At the same time, the pass through rate is close to zero and statistically insignificant at low-productivity firms. This is consistent with our model which predicts that high-productivity firms that compete for workers with other firms need to share the gains from the tax cut with their workers. On the other hand, low-productivity firms which are more likely to employ workers without strong outside options can keep the tax cut amount. This heterogeneity holds both for workers who remain at the same firm and workers who transition to another firm (columns (4) and (5)), although the pass-through rate of the tax cut is higher for those who change employer, which is in line with the predictions of the theoretical model.

5.2 Robustness and Credibility Checks

Parallel trends. Similarly to the employment estimates, the key identifying assumption in our difference-in-difference style regression is that wages in the treated age group would have evolved similarly to those in the control age group in the absence of the payroll tax cut. While this assumption cannot be tested directly, we can test whether the assumption holds in the pre-policy years. We estimate the same regression equation as for the main analysis, but we shift the time window to the pre-reform years and assume pre-reform (hypothetical) treatment years. Panel (a) of Figure 8 shows the estimated pass-through when we estimate regression equation (13) using years 2011-2012 (assuming $t_{reform} = 2012$) and 2010-2011 ($t_{reform} = 2011$). We report the estimated pass-through at low-productivity firms (β_1 from equation (13)) and high-productivity firms ($\beta_1 + \beta_3$ from equation (13)). In both pre-reform placebo analysis, we find no indication for any wage change at high- or low-productivity firms. The effects are therefore specific to the actual treatment year.

SUTVA assumption and changing the treatment and control definitions. Similarly to the employment estimates we also study the sensitivity of our estimates to changing the treatment and control groups to alleviate the concerns related to spillovers to the control group and the potential violation of the SUTVA assumption. Figure 9 shows the pass-through estimates for all firms (Panel (a)) and by firm productivity (Panel (b)). The estimated patterns remain very similar if we define the control group farther away from the age 55 cut-off by using workers who are 52 and 53 years old or 52-year-olds only as the control group. We also explore how the estimates change if we define narrower treatment age groups. We show estimates when the treatment includes only those between 56 and 57 and when it includes only 57-year-olds. The estimated effects are similar in all these specifications, suggesting that our estimates are not sensitive to changing the age window in

the estimation.

Wage changes by tax cut rate. So far, we have assumed a linear relationship between the tax cut rate, TCR_{it-1} and wage changes. We also study the non-parametric relationship by estimating the change in wages for tax cut rate categories separately. In particular, we estimate regression equation (13) but replace the continuous tax cut rate variable with a set of dummy variables showing different levels of the tax cut rate. Figure 10 shows the main estimates separately for low- (blue diamonds) and high- (red squares) productivity firms. In the figure, past wages, w_{it-1}, increase from the left to the right and so the tax cut rate—the size of the (lump-sum) payroll tax cut relative to the wage—falls. The figure demonstrates that at high tax cut rates there is a clear change in wages at high-productivity firms, but not at the low-productivity ones. Furthermore, as the tax cut rate decreases (from left to right) we see a decrease in wage changes at high-productivity firms as we would expect if the wage changes were driven by the tax cut. At low tax cut rate levels the wage changes are small for both high- and low-productivity firms. The non-parametric relationship between tax cut rate and wage changes, therefore, corroborates that the estimated wage changes at high-TFP firms are driven by the tax cut and not something else.

Robustness to including part-time workers. Since in our data we do not perfectly observe hours worked, so far, we have focused on full-time workers whose wage information is more precisely estimated. Column (6) of Table 6 shows the estimated change in wages when we include part time workers in the sample. The estimated pass-through at high-productivity firms declines when including part-time workers (from 60% to 41%) but it remains both economically and statistically significant.

Robustness to two-year change. So far, we have focused on one-year changes post policy. We made this restriction because we wanted to make sure that the policy change itself does not affect the measure of the tax cut rate, TCR_{it-1}, through changes in the previous year's wage. As a robustness check, we redefine the tax cut rate as $TCR_{it-2} = 14500/w_{it-2}$ and study two-year changes. Column (7) of Table 6 shows the estimates when we examine two-year changes. The estimated pass-through is somewhat higher (78% vs. 60% at high-productivity firms). In Panel (b) of Figure 8 we also report two-year wage changes. It suggests that between 2010-2012, the wages of control and treated workers evolved fairly similarly with the divergence happening only when the tax cut was introduced in 2013.

Effect by various firm quality measures. Similarly to the employment estimates, we replicate the heterogeneity analysis in the wage effects using other indicators of firm quality. We report the results in Panel (b) of Figure 7 and in Table 7. Workers at foreign, high-wage, and high-wage-premium firms experienced substantial wage increases, equivalent to almost full pass through. At the same time, workers at domestic, low-wage and low-wage-premium firms did not experience any wage increases.

Based on Table 7, we see that a similar pattern of incidence emerges for a wide class of measures of "good" firms. This suggests that the heterogeneity in incidence that we uncover is not tied to one specific quality measure and is a basic feature of the labor market. Panels (a) and (b) of Figure 7 also demonstrate the heterogeneous incidence of the policy by firm type. While low-quality firms (blue diamonds) respond on the employment margin and not the wage margin, the opposite is true for high-quality firms (red squares).

Effect by education categories. We estimate wage effects by education categories and report the results in Appendix Table B13. Education is defined by the mode of the education level for each four-digit occupation (see Section 4.4 for details—here, to reduce the noise in the estimates, we consider two education categories: primary and lower-secondary on the one hand and upper-secondary and tertiary on the other hand). The table shows that for both education categories the pass-through rate of the tax cut is bigger at high-TFP and high wage premium firms. Also, the pass-through rate is higher and its heterogeneity is stronger at higher education category jobs, where the bargaining channel described in our model is likely to play a more important role (see e.g. Hall and Krueger, 2012).

Effect by firm size. We also examine the heterogeneity of wage effects by two firm size categories, using the same categorization as for the employment effects. The results reported in Appendix Table B9 indicate that qualitatively the pattern of the wage effects is similar both at micro and small firms (size 1-49) and at medium-sized and large firms (size 50+), although the pass-through rate at high-productivity firms is higher among medium-sized and large firms (65%) than among micro and small firms (45%).

5.3 Rent Sharing and Windfall Effects

Recent empirical work shows that firms that received larger rents or windfalls as a result of a tax cut for younger workers, grew more rapidly in the context of Sweden (Saez, Schoefer and Seim, 2019). We study the presence of such windfall effects in the context of the tax cut for older workers in Hungary. The main results are summarized in Appendix Figure B4. We compare firms that have a high share of treated workers aged 55 and above with firms

that have a medium share of such workers. Similarly to Saez, Schoefer and Seim (2019) we find mean reversion in the ratio of the windfall revenues to the total payroll (which we call exposure). Firm size, wages and sales revenue after the reform trend similarly for firms with high and medium shares of treated workers, and so we find no clear indication that windfall effects are important for this population. Interestingly, when we examine the impact of a tax cut on younger workers in Hungary in Section 7.2, we find remarkably similar findings as in Saez, Schoefer and Seim (2019).[32] This suggests that the lack of windfall effects for older workers is unlikely to reflect the different economic environment, and that the tax cut impacts younger and older workers differently.

Another important finding in Saez, Schoefer and Seim (2019) is that firms shared the rents coming from the tax cut equally between young treated and untreated workers. Such rent sharing would work against finding any wage effects in our empirical design that compares the wage change between treated and untreated workers. Still, as we demonstrated above, we find clear indication of wage changes between treated and untreated workers for high-productivity firms.

Nevertheless, we directly assess the implication of rent sharing in column (8) of Table 6. We calculate the firm-level rent as in Saez, Schoefer and Seim (2019) by taking the ratio of all the tax cuts instituted in 2013 (including those affecting younger workers and workers in elementary occupations) and the pre-reform total wage bill. We include this windfall measure in equation (13) and interact it with the age categories, the post reform dummy, and the post reform by treatment age dummy, and the interaction with the tax cut rate variable, TCR_{it-1} (including all other variables that are interacted with tax cut rate in equation (12)). The results show that including the windfall effects in the regression does not change the estimated pass-through at high- and low-productivity firms. If anything the estimated pass-through effects are slightly larger at high-productivity firms (65% instead of 60% in the benchmark estimate) and still close to zero at low-productivity firms once we take into account the windfall effects. Appendix Table B12 also shows that the windfall effects do not change the pass-through estimates when other firm quality measures are applied.

The treated post-reform windfall coefficient in column (8) of Table 6 suggests that firms hit by larger windfall increase the wages of treated workers slightly more than the wages of untreated workers. Nevertheless, these effects are less important at lower wages, where the tax cut played a more important role. Furthermore, the effect of the windfall shock on wages was limited given that the average windfall rate was 2.7% in our sample. Overall, these

[32]Appendix Figure D5 implements the same windfall analysis for younger workers. Similarly to Saez, Schoefer and Seim (2019), we find no pre-trends between high exposure and medium exposure firms among younger workers, but document an increase in revenues and employment at high exposure firms (relative to medium exposure firm) after the tax cut.

findings suggests that our results are unlikely to be altered by the rent sharing documented in Saez, Schoefer and Seim (2019).

6 Welfare Analysis

Our results suggest that the payroll tax cut targeted at workers above 55 increased the employment of the targeted workers at low-productivity firms and increased their wages at high-productivity firms. In this section we evaluate the policy's welfare impact, taking into account its costs and fiscal externalities.

We follow the method proposed by Hendren and Sprung-Keyser (2020) to calculate the Marginal Value of Public Funds (MVPF) for the age-dependent payroll tax cut. We apply the following formula:

$$\text{MVPF} = \frac{\text{WTP}}{\text{Net Government Cost}}, \tag{14}$$

where the Willingness to Pay (WTP) is the sum of individuals' willingness to pay for the policy out of their own income and the net cost is the net impact of the policy on the government budget.

The WTP consists of three parts. First, the part of the tax cut that is received by workers enters workers' WTP with a positive sign. To calculate this, we first calculate the per capita average amount of the tax cut (using the employment rate and average effective tax cut). Then, based on the estimated pass-through in Table 6, we determine the fraction of the tax cut that goes to workers. Second, workers who gain employment as a result of the tax cut lose their unemployment benefits which enters their WTP with a negative sign. Here, we rely on the estimated treatment effects on employment (Table 6) and the average unemployment benefit as observed in our data. Third, workers who gain employment are paid wages by their employers which enters their WTP with a positive sign—to calculate this part of the WTP, we estimate the employment effect by wage categories. The net cost is the sum of the tax cut minus the benefits a non-employed person receives minus the taxes paid after the additional wage due to increasing employment.

We calculate the MVPF two different ways. Under the first approach, we assume the policy maker only cares about workers' welfare and the social marginal utility of employers is zero. In this version, we do not incorporate the part of the tax cut that goes to employers into the WTP. In an alternative calculation, we assume that social marginal utility is the same on workers and employers and so we incorporate the part of the tax cut that goes to employers into the WTP.

We present the calculations in Table 8. When the policy maker only cares about workers'

welfare, the overall MVPF is 0.27. The low MVPF reflects the fact that our estimates imply that most of the tax cut benefited employers. The MVPF is much larger at high-productivity firms (0.51) than at low-productivity ones, where it is close to zero. The difference is mainly due to the higher pass-through rate of the tax cut to workers at high-productivity firms. Our calculation, therefore, highlights that if policy makers mainly care about workers' welfare, they should target high-productivity firms with the tax cut.

Once we include the part of the tax cut going to employers into the WTP, the relationship between the MVPF and firm productivity flips: payroll tax cuts targeting high-productivity firms have lower MVPF (0.99) than payroll tax cuts targeting low-productivity firms (1.52). This is because when the incidence of the tax cut between employers and employees does not matter, the employment creation effect will dominate the welfare calculations. Since employment creation mainly takes place at low-productivity firms, the MVPF will be larger for targeting these firms with the tax cut.

We can also compare our MVPF estimates to those estimated in the literature. Paradisi (2021) calculates that the MVPF is 1.02 for the young worker tax cut analyzed by Saez, Schoefer and Seim (2019). Our comparable MVPF calculation that gives equal weight to firms and workers gives a slightly larger 1.22.

7 Effect on Women and Younger Workers

7.1 Women

We exclude women from the main analysis to make sure that our results are not driven by a pension policy introduced in 2011 for women. The "Women 40" policy gives an early retirement option to women with 40 years of work credits, regardless of age. Because we do not observe the full employment history over the lifecycle, we cannot assess their eligibility to the early retirement option. Nevertheless, in this section we estimate the same difference-in-differences model for women. Here we summarize the main results and in Appendix Section C we provide further details.

Overall, results for men and women are very similar. Appendix Tables C1 and C2 show that the payroll tax cut is estimated to increase private sector employment of women by 0.51 percentage point (vs. 0.53 percentage point for men) in the 55-57 age group compared to the 52-54 age group over the years 2013-2015. The heterogeneous employment patterns by firm productivity are also similar among men and women: employment increases more at low-TFP firms, albeit the difference by firm type is smaller for women. The firm heterogeneity patterns are also present if we look at job categories based on wage and education level

separately, suggesting that the heterogeneity is driven by firms. Appendix Figure C1 shows the wage effects for women by firm productivity at different levels of tax cut rate. Similarly to men, wages increase only at high-TFP firms and only at high tax cut rates.

7.2 Younger Workers

Besides the payroll tax cut for older workers, a similar tax cut was also introduced for workers under age 25 in 2013. The tax cut led to a 6.6% reduction in the labor cost. We apply the same difference-in-differences model as for the older population to examine the impact of the policy on these workers. We summarize the the basic results here and provide further details in Appendix Section D.

The overall impact of the tax cut on employment was larger for younger workers than for older workers (see Appendix Table D1). The estimated employment elasticity with respect to the cost of labor is -0.77. We find similar heterogeneity in the employment responses of younger workers though the heterogeneity is more sensitive to the firm quality measure applied. When we use TFP as the measure of firm quality the employment elasticity at low-TFP firms is close to one, and around two-third of that at high-TFP firms. When we measure quality by AKM firm effects or foreign/domestic ownership we find more striking heterogeneity: most of the employment responses emerge at low-quality firms, while responses at high-quality firms are close to zero as we see for older workers (see Appendix Figure D3).

Turning to wages, we find no indication for significant wage differences between treated and untreated younger workers (see Appendix Figure D4) or significantly higher wage growth at firms that were highly exposed to the tax cut as they employed many young worker before the tax policy (see Appendix Figure D5). As a result, firms with many young workers experienced a large windfall gain following the tax cut. Furthermore, we find that these more exposed firms grew more rapidly in terms of employment and revenue following the tax cut.

Overall these findings are broadly in line with the labor market responses documented by Saez, Schoefer and Seim (2019) in response to the young worker tax cut in Sweden. Nevertheless, our finding that employment creation predominantly happens at low-productivity firms is a so far undocumented feature of the policy. Furthermore, while there are many similarities in the responses of younger and older workers in Hungary, there are also notable differences. For instance, we find no indication for wage changes for younger workers, while we estimate clear wage differences for older workers. This difference could be driven by wage rigidities that constrain firms' pass-through differently for younger and older workers. For

instance, passing through the tax cut to younger workers could mean a wage increase for a 22-24 years old and then a wage cut once they reach age 25. At the same time, passing through the tax cut would simply mean that once age 55 is reached a pay raise is implemented. The latter might be more feasible than the former because workers dislike pay cuts (Bewley, 1998; Kaur, 2019).

Another difference is that the heterogeneity in employment effects seems to be less pronounced for younger workers than for older workers, at least for certain quality measures. Through the lens of our illustrative model, this could be explained by the fact that there are many more new entrants in the labor market for younger workers than in the labor market for older workers. Workers who are entering the labor market, or workers in probationary period, have no credible outside option and so firms can hire them and extract all the rents. If the share of these types of workers is large in a labor market, there will be smaller differences in the hiring incentives of low- and high-productivity firms. In line with that interpretation, we show that the employment differences between low- and high-TFP firms are less pronounced among workers who enter the labor market at later ages and so have shorter work history (if any) by age 22-24. At the same time, more experienced workers entering the labor market at younger ages (age 18-19) seem to be affected by the tax cut just like older workers: employment increases only at low-TFP firms (Table D2).

8 Conclusion

This paper studies the implications of payroll tax cuts in a setup where firms play an active role in wage determination. A key prediction of our framework is that the tax policy can have heterogeneous impacts across firm types. High-productivity firms offering good jobs respond to the tax cut by raising wages, while low-productivity firms will respond mainly on the employment margin. As a result, the tax policy will change the composition of jobs in the economy.

We exploit the introduction of age-dependent payroll tax reductions in Hungary and use rich administrative data to provide empirical support for these predictions. In response to a large tax cut, we estimate that both employment and wages increased among treated older workers. However, there are substantial heterogeneities across firm types. The positive effect of the payroll tax cut on employment is driven by low-productivity firms, while the wage effect is mainly driven by high-productivity firms. Overall, our results highlight that at low-productivity firms, the incidence of payroll tax cuts mainly falls on firms, while at high-productivity firms, the incidence mainly falls on workers. Furthermore, universal tax cuts supporting all types of jobs and firms the same way could have some unintended

consequences by creating bad jobs with little value for many workers. This aspect of payroll tax cuts should be considered in future evaluations of such policies (Rodrik and Stantcheva, 2021).

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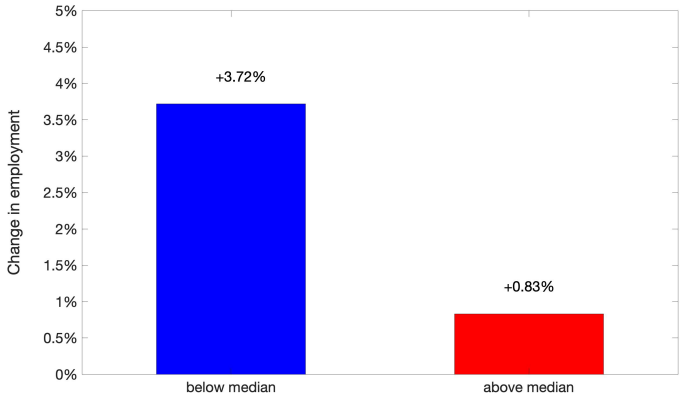
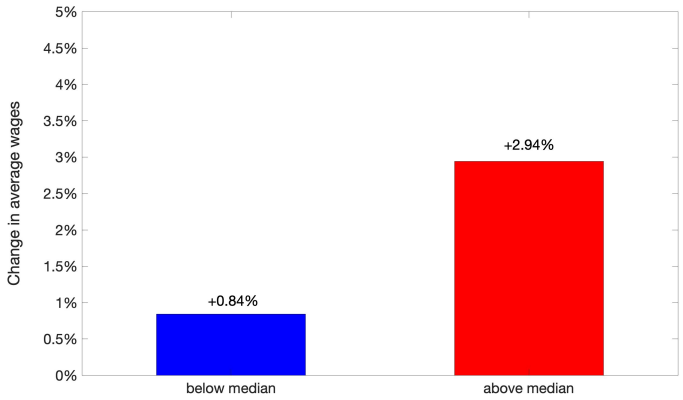
Figures and Tables

Figure 1: Employment and Wage Changes in Response to a Payroll Tax Cut by Firm Productivity in the Search Model

(a) Employment Change

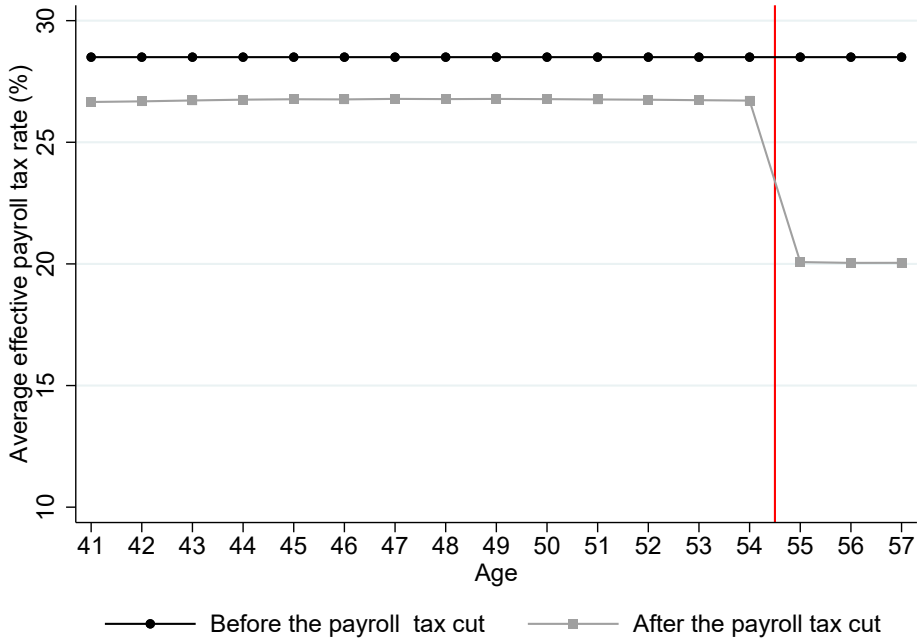


(b) Wage Change for Incumbent Workers



Note: Figure shows the effect of a tax cut that is 6% of the average wage in the economy (similar in size to the tax cut that was introduced in Hungary). We numerically solve the model presented in Section 2 using the functional form assumptions and parameter values usually applied in the literature (see Appendix Section A.6). Panel (a) shows the impact of the tax cut on employment in percentage terms by productivity category of the employer (below- or above-median productivity). Panel (b) shows the impact of the tax cut on the average wages of incumbent workers by productivity category of the current employer (below- or above-median productivity). Incumbent workers are those workers who are not newly hired from unemployment in this period. Incumbents include workers who worked at their current firm in the previous period and also those who worked at another firm in the previous period, but were poached in this period.

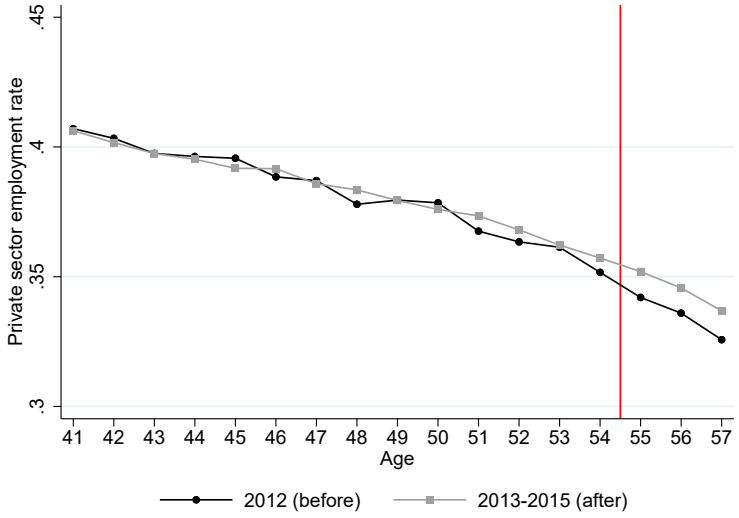
Figure 2: Employers' Social Security Contribution Rate by Workers' Age



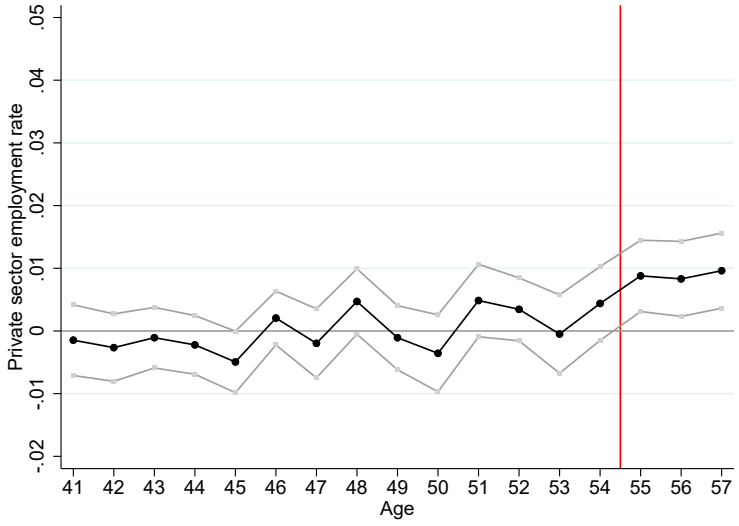
Note: Figure shows the average employer social security contribution rate by worker age for male workers in the private sector. Before the implementation of the payroll tax cut, the payroll tax rate was a flat 28.5%. Between 2013-2015 (after the implementation of the cut) all individuals over age 55 experienced a lump-sum tax cut of HUF 14,500 per month (around 6% of the average salary). Certain individuals were also eligible for the tax cut independently of their age (see Section 3.1 for the details).

Figure 3: Employment in Private Sector Companies by Age

(a) Private Sector Employment Rate

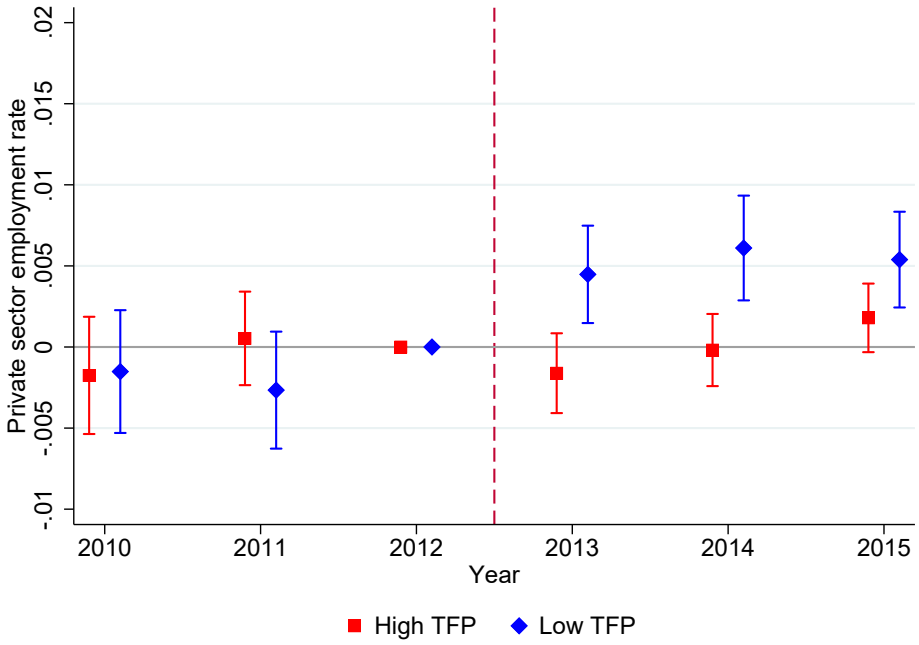


(b) Change in Private Sector Employment Rate



Note: Panel (a) of the figure shows the private sector employment rate by age before and after the introduction of the age-specific payroll tax cut. The black line shows the employment rate in year 2012 (before the implementation of the payroll tax cut) and the gray line for years 2013-2015 (after the implementation of the payroll tax cut). Panel (b) shows the difference in employment rates between years 2012 and 2013-2015 relative to the average change between ages 41 and 54, with the 95% confidence interval (standard errors clustered at the age × period level). The vertical red line shows the age threshold where the tax cut became effective from 2013.

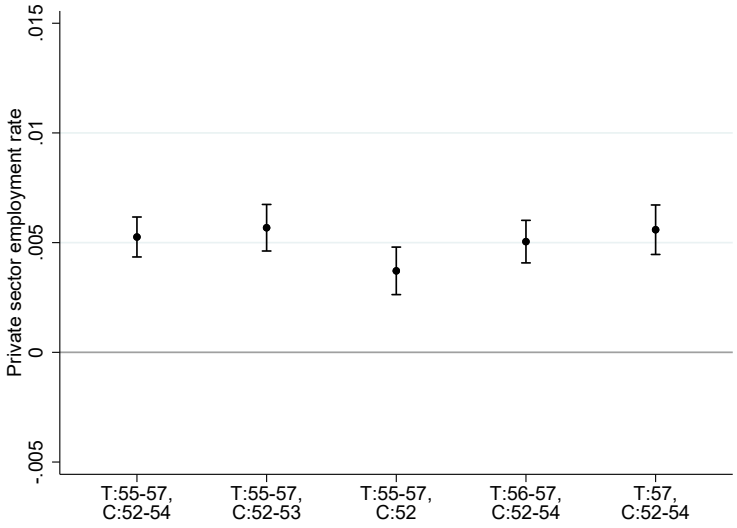
Figure 4: Evolution of Employment at Low- and High-Productivity Firms



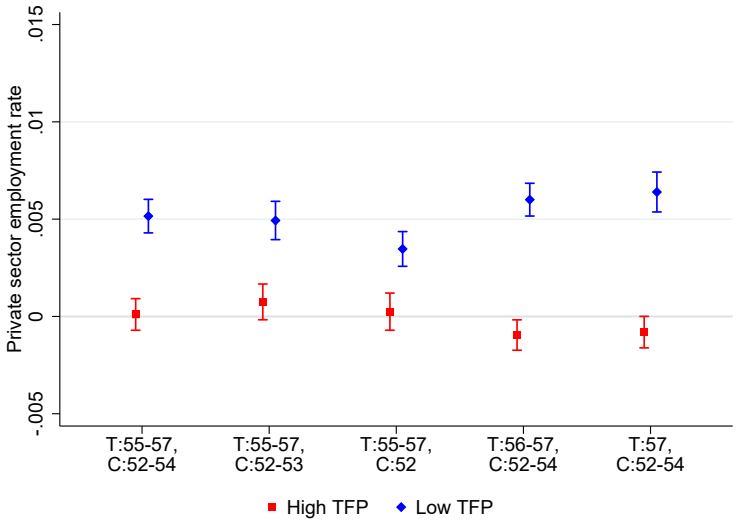
Note: Figure shows the evolution of the employment rate at low- and high-productivity (TFP) firms over time. We report the difference in employment between the 55-57 age group that was affected by the payroll tax cut and the 52-54 age group that was not affected by the tax cut relative to the difference in 2012. In particular we report β_h coefficient of the regression equation (10) where the outcome variable is being employed at an above-median (in red) or at a below-median (in blue) TFP firm. 95% confidence intervals are reported with standard errors clustered at the age $\times$ period level.

Figure 5: Employment Estimates Using Alternative Control and Treatment Definitions

(a) Employment at all Private Sector Firms



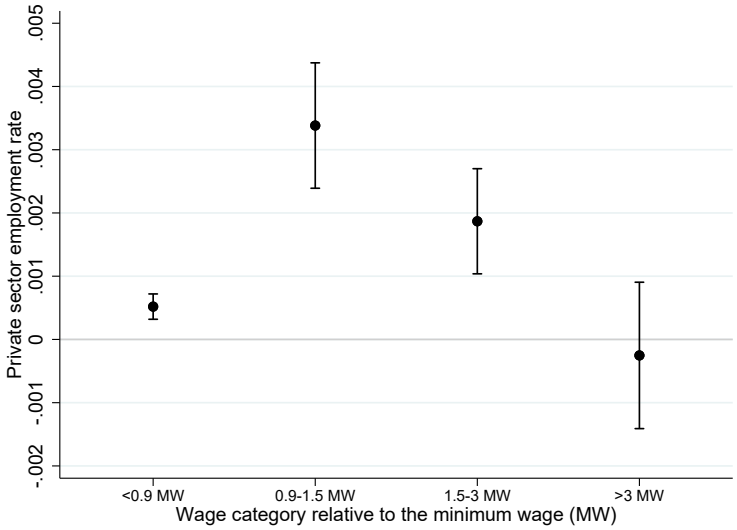
(b) Employment by Productivity



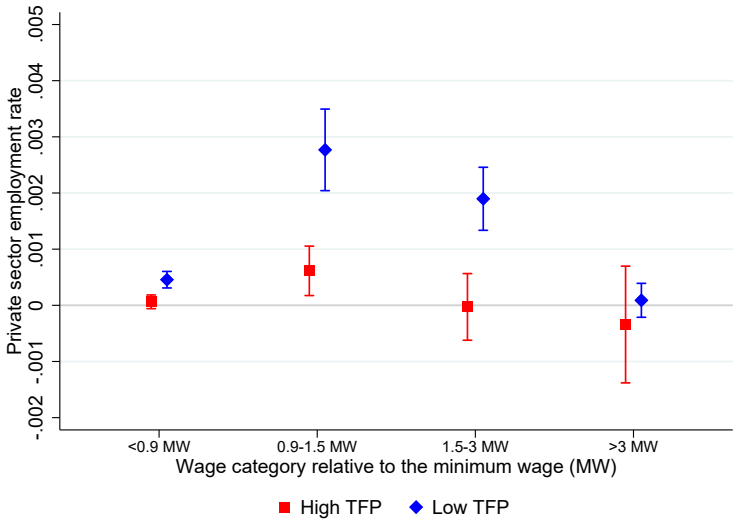
Note: Figure shows the difference-in-differences estimates of the impact of the payroll tax cut on private sector employment based on estimating equation (9) for alternative control and treatment definitions. The estimates show the the change in employment in the treatment age group relative to the change in employment in the control age group. Panel (a) shows overall estimates and Panel (b) shows estimates separately for above-median (in red) and below-median (in blue) productivity (TFP) firms. In both panels, the first estimate replicates our baseline results and the subsequent estimates change the age composition of the control ("C") or treatment ("T") groups. 95% confidence intervals are reported with standard errors clustered at the age $\times$ period level.

Figure 6: Impact of the Payroll Tax Cut Across the Wage Distribution

(a) Employment at all Private Sector Firms



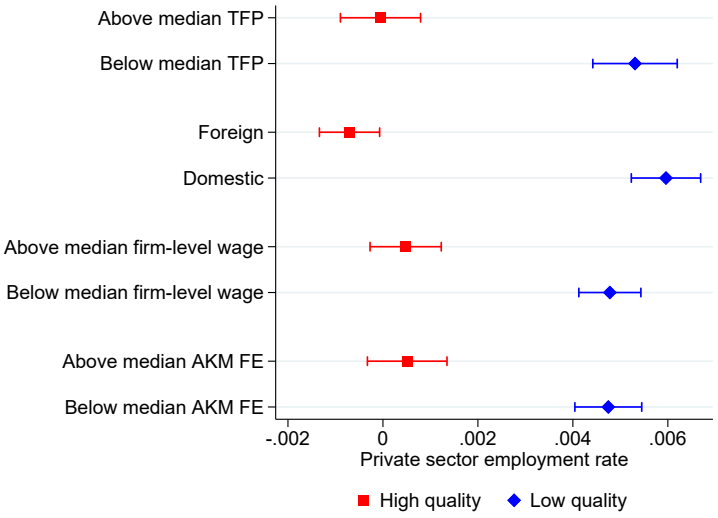
(b) Employment by Productivity



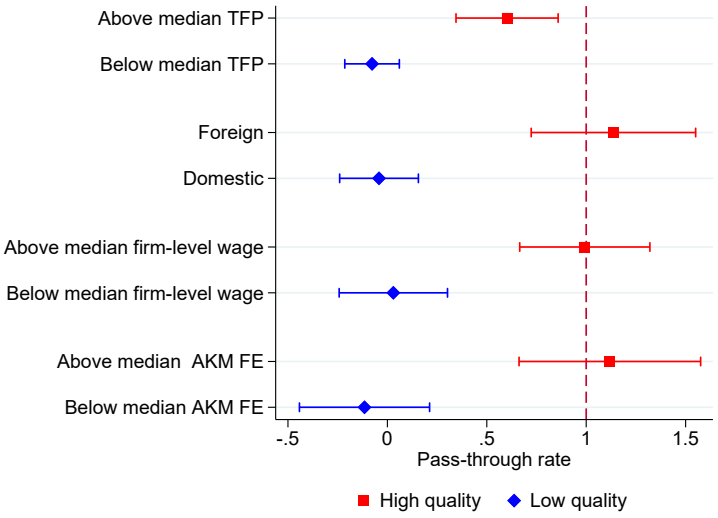
Note: Figure shows difference-in-differences estimates of the impact of the payroll tax cut on private sector employment in different wage bins. The estimates are based on equation (9), where the outcome variable is being employed in a private sector company in a given wage bin (less than the 90% of the minimum wage; between 90% and 150% of the minimum wage; between 150% and 300% of the minimum wage; or above 300% of the minimum wage). The difference-in-differences estimates compare the change in employment among the 55 to 57 age group that was affected by the payroll tax cut with the change in employment among the 52 to 54 age group that was not affected by the tax cut. Panel (a) shows employment changes at all private sector companies and Panel (b) shows estimates separately for above-median (in red) and below-median (in blue) productivity (TFP) firms. In both panels, we present separate estimates by wage level. 95% confidence intervals are reported with standard errors clustered at the age × period level.

Figure 7: Employment and Wage Changes in Private Sector Companies: Alternative Firm Quality Measures

(a) Employment Changes



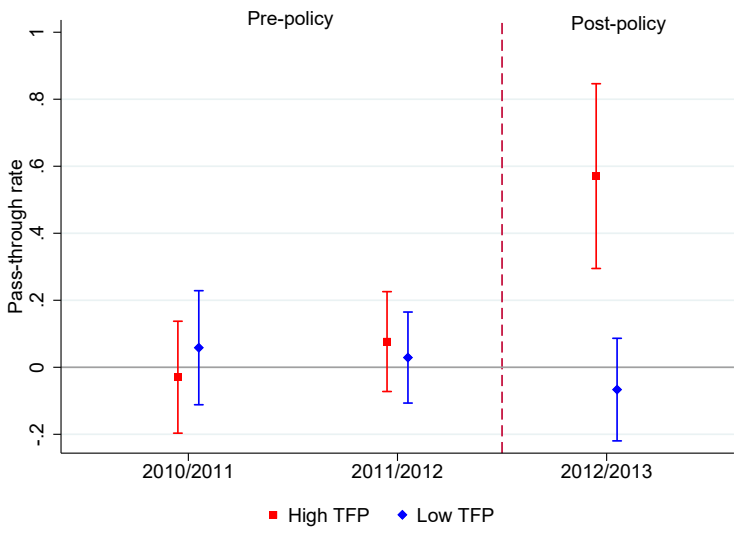
(b) Wage Changes



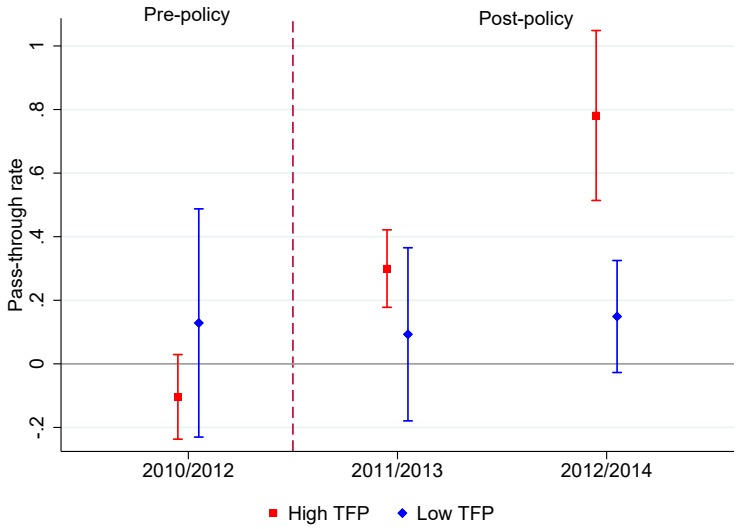
Note: Panel (a) of figure shows difference-in-differences estimates of the impact of the payroll tax cut on private sector employment based on estimating equation (9). Panel (b) shows wage estimates (pass-through rate) separately for above-median (in red) and below-median (in blue) quality firms. The pass-through rate at below-median firms is β_1, the pass-through rate at above-median firms is the sum of β_1 and β_3 in equation (13). The red vertical line corresponds to a pass-through rate of one—all the tax cut passed through to workers by raising their wages. The difference-in-differences estimate compares the change in outcome (employment or wages) among the 55 to 57 age group that was affected by the payroll tax cut with the change in employment and wages among the 52 to 54 age group that was not affected by the tax cut. In both panels, the first two rows replicate our baseline results with high- and low-productivity firms. The third and the fourth rows uses foreign ownership (more than 50%) as a quality measure. In Hungary, foreign-owned firms are the most productive firms offering the highest paying, highest quality jobs. The fifth and sixth rows measure quality based on average wages, while the last two rows measure quality using the firm-level wage premium estimated using an Abowd, Kramarz, Margolis (AKM) style decomposition. 95% confidence intervals are reported with standard errors clustered at the age × period level.

Figure 8: Evolution of Wage Changes in Private Sector Companies

(a) One-Year Wage Changes



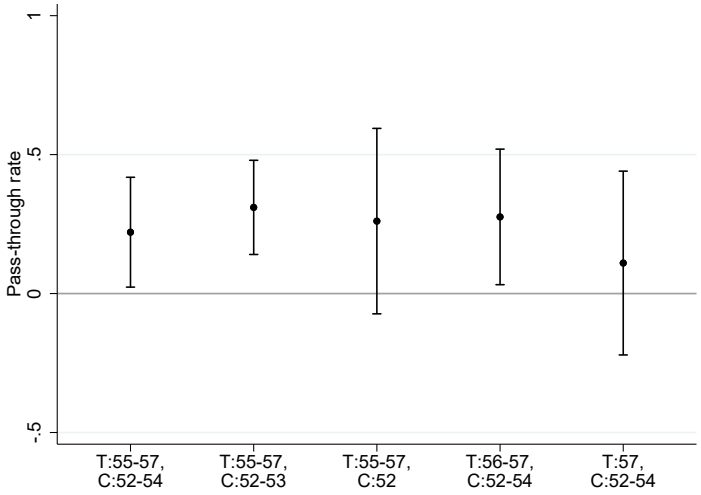
(b) Two-Year Wage Changes



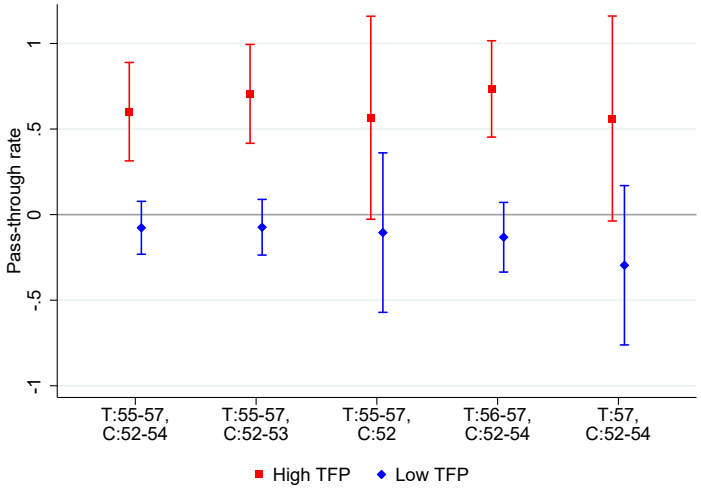
Note: Figure shows difference-in-differences estimates of the pass-through rate of the payroll tax cut to private sector wages separately for low- and high-productivity (TFP) firms. Estimates are based on equation (13), where we compare the change in wages among the 55-57 age group that was affected by the payroll tax cut with the change in wages among the 52 to 54 age group that was not affected by the tax cut. The pass-through rate at low-TFP firms (blue diamonds) is β_1, the pass-through rate at high-TFP firms (red squares) is the sum of β_1 and β_3 in equation (13). Each result is based on the change in wages between the years indicated on the x-axis. Panel (a) shows changes over one-year intervals. The change between 2010 and 2011 and between 2011 and 2012 are before the payroll tax cut was introduced and so those estimates serve as placebo tests. Panel (b) shows changes over two-year intervals. The change between 2010 and 2012 is before the payroll tax cut was introduced and so that estimate serves as a placebo test. 95% confidence intervals are reported with standard errors clustered at the age $\times$ period level.

Figure 9: Wage Changes Using Alternative Control and Treatment Definitions

(a) Wages at all Private Sector Firms

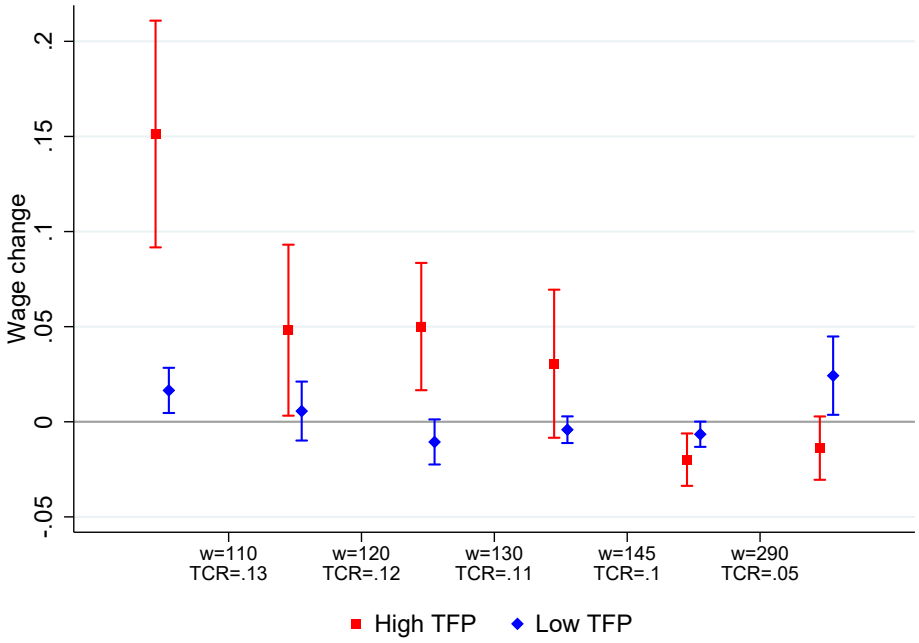


(b) Wages by Productivity



Note: Figure shows difference-in-differences estimates of the pass-through rate of the payroll tax cut on private sector wages separately for low- and high-productivity (TFP) firms. Estimates are based on equation (13), where we compare the change in wages among the 55-57 age group that was affected by the payroll tax cut with the change in wages among the 52 to 54 age group that was not affected by the tax cut. Panel (a) shows overall estimates and Panel (b) shows estimates separately for above-median (in red) and below-median (in blue) TFP firms. In both panels, the first estimate replicates our baseline results and the subsequent estimates change the age cutoffs for the control ("C") or treatment ("T") groups. In Panel (a), the pass-through rate is β_1 in equation (12). In Panel (b), the pass-through rate at low-TFP firms (blue diamonds) is β_1 and the pass-through rate at high-TFP firms (red squares) is the sum of β_1 and β_3 in equation (13). 95% confidence intervals are reported with standard errors clustered at the age $\times$ period level, except for the third and fifth estimates points (T:55-57, C:52 and T:57, C:52-54), where we do not cluster the standard errors as one cluster would capture the entire treatment or control age group.

Figure 10: Wage Changes at Different Levels of Lagged Wages



Note: Figure shows difference-in-differences estimates of the payroll tax cut on private sector wages separately for low- and high-productivity (TFP) firms by lagged wage. The payroll tax cut was 14,500 HUF and so the tax cut rate, $TCR_{it-1} = 14,500/w_{it-1}$, falls as lagged wages increase. Estimates are based on a modified version of equation (13), where the linear tax cut rate TCR_{it-1} in the last interaction term is replaced with categories of the tax cut rate TCR_{it-1}. We report the cut-off values of lagged wages (in thousands of Hungarian forints) and the corresponding tax cut rates TCR_{it-1} on the x-axis of the figure. The estimates display the change in log wages among the 55 to 57 age group that was affected by the payroll tax cut relative to the change in log wages among the 52 to 54 age group that was not affected by the tax cut for above-median (in red) and below-median (in blue) TFP firms. 95% confidence intervals are reported with standard errors clustered at the age × period level.

Table 1: Summary Statistics

	(1) Age 52-54 (Control)	(2) Age 55-57 (Treated)
Panel A: Labor market characteristics		
Private sector employment	0.34	0.32
Monthly private sector wage (HUF)	218,529	217,000
White collar job (private sector workers)	0.31	0.31
Panel B: Firm quality composition		
Above-median TFP	0.49	0.48
Above-median AKM firm effect	0.49	0.48
Above-median firm-level average wage	0.51	0.51
Foreign-owned	0.23	0.22
Panel C: Industry composition		
Agriculture	0.08	0.08
Manufacturing	0.35	0.36
Construction	0.10	0.10
Wholesale and retail trade	0.11	0.10
Accommodation and food service	0.02	0.02
Transportation and storage	0.12	0.10
Administrative and support	0.05	0.06
Number of individuals	123,154	141,875

Note: Table shows summary statistics for the treatment and and control groups in 2012. The treatment group comprises ages 55-57 and the control group comprises ages 52-54. Panel A shows labor market characteristics, including the share of workers employed in the private sector, the average monthly (full-time equivalent) wage of workers employed in the private sector, and the share of workers employed in the private sector in white collar jobs. Panel B shows measures of firm quality composition, including the share of workers at firms with above-median firm quality and at foreign-owned firms. We calculate the median quality (measured by TFP, AKM firm effects, and average wage) based on all prime age workers. Firms are categorized as foreign-owned if foreign ownership is at least 50%. Further details on quality measures are provided in Section 3. Panel C shows the share of workers in various industries.

Table 2: Employment Effects of the Tax Cut

	(1) All firms	(2) Low TFP	(3) High TFP
Panel A: Change in private sector employment probability			
— After × Treated	0.0053***	0.0053***	-0.0001
	[0.0005]	[0.0005]	[0.0004]
Panel B: Percent change in employment			
—Employment without tax cut	0.330	0.167	0.163
—Employment with tax cut	0.335	0.172	0.163
—Percent change in employment	1.59%	3.18%	-0.03%
Panel C: Percent change in labor cost $(1+\tau_{ss})$			
—Labor cost without tax cut	1.27	1.26	1.28
—Labor cost with tax cut	1.20	1.18	1.22
—Percent change in labor cost	-5.27%	-6.02%	-4.45%
Panel D: Implied elasticity (Panel B/Panel C)			
— Elasticity	-0.30	-0.53	0.01
	[0.03]	[0.05]	[0.06]

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: Panel A of the table shows difference-in-differences estimates of the impact of the payroll tax cut on private sector employment for all firms (column 1) and separately for below-median (column 2) and above-median (column 3) TFP firms in Panel A. In particular, we report the β coefficient from regression equation (9) with the outcome variable being employed at a private sector firm (column 1), at a private sector firm with below-median productivity (column 2) and at a private sector firm with above-median productivity (column 3). The β coefficient estimates the change in employment among the 55 to 57 age group that was affected by the payroll tax cut relative to the change in employment among the 52 to 54 age group that was not affected by the tax cut. Panel B calculates the percent change in employment using the difference-in-differences estimates from Panel A. The first row shows the employment rate in the treatment and control age groups in 2012, the year before the introduction of the payroll tax cut. The second row adds to that baseline the estimated change from Panel A. The third row shows the percent change in employment relative to the baseline. Panel C calculates the percent change in labor cost using an analogous difference-in-differences estimation for tax rates. Firms' labor cost is net wage times $(1+\tau_{ss})$, where τ_{ss} is the employer social security contribution. The reform cut τ_{ss} for workers in the treatment group. The first row shows the average labor cost in the control group between 2013-2015. The second row calculates the average labor cost for the treatment group taking into account the tax cut. The third row calculates the percent change in the labor cost caused by the tax cut. Panel D calculates the implied employment elasticity with respect to the wage change by taking the ratio of the percent change in employment (Panel B) and labor cost (Panel C). Standard errors are reported in brackets, clustered at the age × period level. ($N = 9,003,984$ individual-months)

Table 3: The Effect of the Tax Cut on Labor Market Status

	(1)
Private sector employment (41%)	0.0096***
	[0.0006]
Public sector employment (6.2%)	0.0016***
	[0.0003]
Self-employment (9.7%)	-0.0014***
	[0.0003]
Inactive/unemployed (42%)	-0.0101***
	[0.0007]

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: Table shows the impact of the payroll tax cut on labor market status. Labor market status is determined based on four mutually exclusive categories: all type of private sector employment (41% of the 52-57 years old), public sector employment (6.2% of the 52-57 years old), self-employment (9.7% of the 52-57 years old) and inactivity/unemployment (42% of the 52-57 years old). To make sure that these categories are mutually exclusive, private sector employment (contrary to the benchmark analysis) also includes single-entry bookkeeping firms and firms with more than 10,000 workers (see Section 3.2 and for separate estimates for these firm categories see Table B2). The population share of each labor market status category is reported in parentheses. We report the difference-in-difference estimates from equation (9) using being employed in the private sector (row 1), being employed in the public sector (row 2), being self-employed (row 3) and being inactive or unemployed (row 4) as the outcome variable. The difference-in-differences estimate compares the change in the outcome variable among the 55 to 57 age group that was affected by the payroll tax cut relative to the change in the outcome variable among the 52 to 54 age group that was not affected by the tax cut. Standard errors are reported in brackets, clustered at the age $\times$ period level. ($N = 9,003,984$ individual-months)

Table 4: Employment Effects of the Tax Cut by Subgroups

	(1)	(2)	(3)	(4)	(5)	(6)
		Employment			Elasticity	
	All firms	Low TFP	High TFP	All firms	Low TFP	High TFP
Panel A: By wage						
Jobs paying at most 1.5×minimum wage	0.0039***	0.0032***	0.0007***	-0.43	-0.48	-0.31
	[0.0005]	[0.0004]	[0.0002]	[0.06]	[0.06]	[0.09]
	{35%}	{27%}	{8%}			
	⟨0.1239⟩	⟨0.0922⟩	⟨0.0316⟩			
Jobs paying above 1.5×minimum wage	0.0016***	0.0020***	-0.0004	-0.17	-0.55	0.07
	[0.0005]	[0.0003]	[0.0005]	[0.05]	[0.08]	[0.09]
	{65%}	{24%}	{40%}			
	⟨0.2221⟩	⟨0.0748⟩	⟨0.1473⟩			
Panel B: By occupation						
Low-paid occupations	0.0028***	0.0030***	-0.0001	-0.29	-0.55	0.03
	[0.0004]	[0.0003]	[0.0002]	[0.04]	[0.05]	[0.05]
	{51%}	{28%}	{24%}			
	⟨0.1716⟩	⟨0.0956⟩	⟨0.0761⟩			
High-paid occupations	0.0024***	0.0023***	0.0001	-0.25	-0.47	-0.02
	[0.0006]	[0.0003]	[0.0005]	[0.06]	[0.06]	[0.11]
	{49%}	{19%}	{30%}			
	⟨0.1743⟩	⟨0.0716⟩	⟨0.1028⟩			
Panel C: By education						
Primary and lower-secondary education jobs	0.0038***	0.0037***	-0.0001	-0.29	-0.54	0.02
	[0.0005]	[0.0004]	[0.0003]	[0.04]	[0.06]	[0.05]
	{70%}	{37%}	{33%}			
	⟨0.2354⟩	⟨0.1140⟩	⟨0.1214⟩			
Upper-secondary education jobs	-0.0000	0.0004**	-0.0004	0.00	-0.22	0.34
	[0.0003]	[0.0002]	[0.0003]	[0.10]	[0.11]	[0.26]
	{16%}	{8%}	{8%}			
	⟨0.0547⟩	⟨0.0256⟩	⟨0.0291⟩			
Tertiary education jobs	0.0013***	0.0011***	0.0001	-0.54	-0.69	-0.15
	[0.0003]	[0.0002]	[0.0003]	[0.12]	[0.13]	[0.44]
	{14%}	{7%}	{7%}			
	⟨0.0528⟩	⟨0.0258⟩	⟨0.0270⟩			

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: Table shows difference-in-differences estimates of the impact of the payroll tax cut on private sector employment based on estimating equation (9) separately for various subgroups. Panel A considers employment in jobs paying above vs. below 150% of the minimum wage. Panel B considers employment in occupations with above- vs. below-median average wages in 2012. Panel C considers employment in occupations requiring different levels of education, defined as the modal level of education in the Labor Force Survey in 2012. In each case we estimate the regression equation (9) using employment in a given subgroup (job or occupation) and firm type (all firms in column 1, below-median TFP firms in column 2, and above-median TFP firms in column 3) as the outcome variable. In curly brackets we report the subgroup share within each panel. In angle brackets we report the mean of the outcome variable in May 2012 – the probability of being employed in a given subgroup and firm type. Columns (1)-(3) report the difference-in-differences estimate that compares the change in employment among the 55 to 57 age group that was affected by the payroll tax cut with the change in employment among the 52 to 54 age group that was not affected by the tax cut. In Columns (4)-(6) we calculate the employment elasticity with respect to the wage for all firms (column 4) and separately for below-median (column 5) and above-median (column 6) TFP firms. We obtain percent change in employment by dividing the estimated change in employment with the mean outcome variable reported in angle brackets. Then we divide the percent change in employment with the percent change in labor cost (estimates are not reported, but available on request). Standard errors are reported in brackets, clustered at the age × period level. ($N = 9,003,984$ individual-months)

Table 5: Employment Effects of the Tax Cut for New Entrant and Incumbent Workers and Firms

	(1)	(2)	(3)
		Employment	
	All firms	Low TFP	High TFP
Panel A: New entrant or incumbent workers			
New entrant workers	0.0015***	0.0014***	0.0001
	[0.0002]	[0.0002]	[0.0001]
	⟨0.0425⟩	⟨0.0267⟩	⟨0.0159⟩
Incumbent workers	0.0038***	0.0039***	-0.0001
	[0.0005]	[0.0004]	[0.0004]
	⟨0.2873⟩	⟨0.1409⟩	⟨0.1464⟩
Panel B: New entrant or incumbent firms			
New entrant firms	0.0001	0.0002*	-0.0001***
	[0.0001]	[0.0001]	[0.00004]
	⟨0.0054⟩	⟨0.0045⟩	⟨0.0008⟩
Incumbent firms	0.0052***	0.0051***	0.0001
	[0.0005]	[0.0005]	[0.0004]
	⟨0.3247⟩	⟨0.1625⟩	⟨0.1622⟩
Panel C: Firms established before or after 2012			
Firms established after 2012	-0.0001	0.0002*	-0.0003***
	[0.0001]	[0.0001]	[0.0001]
	⟨0⟩	⟨0⟩	⟨0⟩
Firms existed in 2012	0.0053***	0.0051***	0.0002
	[0.0004]	[0.0004]	[0.0004]
	⟨0.3301⟩	⟨0.1670⟩	⟨0.1631⟩

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: Table shows difference-in-differences estimates of the impact of the payroll tax cut on private sector employment based on estimating equation (9) for all firms (column 1) and separately for below-median (column 2) and above-median (column 3) TFP firms and for new entrant and incumbent workers and firms. In Panel A we study the change in employment for new entrants, who entered the labor market in the current year and so have less than 12 months employment, and for incumbent workers who have been continuously employed in the previous 12 months. In panel B we study the impact separately for new entrant firms, which were established in the current year and incumbent firms, which already existed in the previous year. In panel C we study separately the employment change at firms that existed before the payroll tax cut and at firms that were established after the payroll tax cut. In each panel the sum of new entrants and incumbents adds up to total employment and the employment rate in each of these categories (relative to the total population) in May 2012 is shown in angle brackets. In panel C the employment rate is zero because there is no employment in May 2012 at firms established after 2012. The difference-in-differences estimate compares the change in employment among the 55 to 57 age group that was affected by the payroll tax cut with the change in employment among the 52 to 54 age group that was not affected by the tax cut. Standard errors are reported in brackets, clustered at the age × period level. ($N = 9,003,984$ individual-months)

Table 6: Wage Effects of the Tax Cut

	(1) log(wage)	(2) log(wage)	(3) log(wage)	(4) log(wage)	(5) log(wage)	(6) log(wage)	(7) log(wage)	(8) log(wage)
After × Treated	0.022	-0.019*	0.008	0.007	-0.026	0.021**	-0.021**	0.011
	[0.018]	[0.010]	[0.007]	[0.006]	[0.113]	[0.009]	[0.009]	[0.016]
After × Treated × TCR		0.221**	-0.077	-0.071	0.249	-0.191**	0.149*	-0.129
		[0.090]	[0.070]	[0.053]	[0.925]	[0.085]	[0.081]	[0.215]
High TFP × After × Treated			-0.046***	-0.041***	-0.068	-0.040***	-0.045***	-0.053**
			[0.013]	[0.011]	[0.118]	[0.006]	[0.014]	[0.021]
High TFP × After × Treated × TCR			0.678***	0.602***	0.905	0.600***	0.632***	0.780***
			[0.137]	[0.104]	[1.032]	[0.038]	[0.163]	[0.242]
Windfall rate × After × Treated								0.546*
								[0.277]
Windfall rate × After × Treated × TCR								-5.979**
								[2.588]
Pass-through rate								
All firms		0.221**						
		[0.090]						
Low TFP			-0.077	-0.071	0.249	-0.191**	0.149*	-0.129
			[0.070]	[0.053]	[0.925]	[0.085]	[0.081]	[0.215]
High TFP			0.602***	0.531***	1.154**	0.409***	0.781***	0.651***
			[0.131]	[0.110]	[0.425]	[0.107]	[0.121]	[0.097]
Observations	13,429	97,789	97,789	93,666	4,123	112,713	82,910	97,789
New entrants vs. incumbents	new entrants	incumbents	incumbents	incumbents	incumbents	incumbents	incumbents	incumbents
Workers	all	all	all	same firm	poached	all	all	all
Part-time included	no	no	no	no	no	yes	no	no
One vs. two year change	one	one	one	one	one	one	two	one
Windfall rate included	no	no	no	no	no	no	no	yes

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: Table shows difference-in-differences estimates of the impact of the payroll tax cut on private sector wages. Column (1) estimates the effect on wages for new entrants who entered the labor market in the current year and so have less than 12 months employment using equations (11). Columns (2)-(8) estimate the wage change for incumbent workers (who have been continuously employed in the previous 12 months). Column (2) estimates wage change for all firms using equation (12), while columns (3)-(8) estimate heterogeneity by firm productivity using equation (13). Column (3) shows wage changes for all incumbent workers, while columns (4) and (5) show estimates for workers who stayed at the same firm and workers who were poached to another firm, respectively. In all columns except column (6) we focus on full-time workers. In column (6) we also include part-time workers in the analysis. In all columns except in column (7), we compare the wage changes between 2012 and 2013. In column (7) we study two-year wage changes and compare the wage change between 2012 and 2014. In column (8), we also interact the treatment, age, year, and tax cut rate indicators with the firm specific windfall rate, which reflects the size of the windfall received by the firm as a result of the tax cut. Following (Saez, Schoefer and Seim, 2019)) we calculate this as the (lagged) ratio of age- and occupation specific payroll tax cuts payable after the reform and the total payroll. The difference-in-differences estimate compares the change in wages among the 55-57 age group that was affected by the payroll tax cut with the change in employment among the 52 to 54 age group that was not affected by the tax cut. The pass-through rate at low-productivity firms is the β_1 coefficient on the After × Treated × TCR term in equation (13), while at high-productivity firms it is the sum of the β_1 coefficient and the β_3 coefficient on the High TFP × After × Treated × TCR term in equation (13). Standard errors are reported in brackets, clustered at the age × period level.

Table 7: Wage Effects of the Tax Cut by Various Firm Quality Indicators

	(1) log(wage)	(2) log(wage)	(3) log(wage)	(4) log(wage)
After × Treated	0.008	0.003	-0.004	0.010
	[0.007]	[0.011]	[0.016]	[0.020]
After × Treated × TCR	-0.077	-0.042	0.030	-0.115
	[0.070]	[0.101]	[0.139]	[0.167]
High-quality × After × Treated	-0.046***	-0.068***	-0.054***	-0.072***
	[0.013]	[0.014]	[0.008]	[0.014]
High-quality × After × Treated × TCR	0.678***	1.179***	0.963***	1.235***
	[0.137]	[0.211]	[0.051]	[0.160]
Pass-through rate				
Low-quality	-0.077	-0.042	0.030	-0.115
	[0.070]	[0.101]	[0.139]	[0.167]
High-quality	0.602***	1.137***	0.993***	1.119***
	[0.131]	[0.211]	[0.167]	[0.233]
Observations	97,789	97,789	97,789	97,789
Quality measure	TFP	foreign-owned	firm-level wage	AKM FE
New entrants vs. incumbents	incumbents	incumbents	incumbents	incumbents
Workers	all	all	all	all
Part-time included	no	no	no	no
One- vs. two-year change	one	one	one	one

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: Table shows difference-in-differences estimates of the impact of the payroll tax cut on private sector wages based on estimating equation (13). In each column, we interact all coefficients with an indicator for whether the firm is high quality (above-median with respect to the given quality measure or foreign-owned). In all columns we show the wage changes for all incumbent workers and we focus on full-time workers. In all columns we compare the wage changes between 2012 and 2013 to the wage changes between 2011 and 2012. In column (1) we repeat the results using TFP as a measure of quality reported in column (3) of Table 7. In column (2) we measure quality based on ownership. In Hungary foreign-owned firms are the most productive firms offering the highest-paying, highest-quality jobs. In column (3) we measure firm quality by the average wage the firms pays. Finally, in column (4) we measure firm quality based on the firm-level wage premium estimated using an Abowd, Kramarz, Margolis (AKM) style decomposition. The difference-in-differences estimate compares the change in wages among the 55-57 age group that was affected by the payroll tax cut with the change in employment among the 52 to 54 age group that was not affected by the tax cut. The pass-through rate at low-productivity firms is the β_1 coefficient on the After × Treated × TCR term in equation (13), while at high-productivity firms it is the sum of the β_1 coefficient and the β_3 coefficient on the High TFP × After × Treated × TCR term in equation (13). Standard errors are reported in brackets, clustered at the age × period level.

Table 8: Marginal Value of Public Funds

	(1) All firms	(2) Low TFP	(3) High TFP
(1) Direct cost	5116	2402	2774
(2) Tax cut going to workers	974	-159	1437
(3) Benefit receipt of non-employed who become employed	328	328	-6
(4) Additional net wages of non-employed who become employed	510	473	-10
(5) Additional tax revenue	438	401	-9
(1)-(3)-(5) Net cost	4349	1673	2789
(2)+(4)-(3) Willingness to pay (WTP), workers only	1155	-14	1433
(1)+(4)-(3) Willingness to pay (WTP), workers and firms	5297	2547	2770
Marginal value of public funds (MVPF), workers only	0.27	-0.01	0.51
Marginal value of public funds (MVPF), workers and firms	1.22	1.52	0.99

Note: Table shows estimates of the marginal value of public funds (MVPF) associated with the payroll tax cut. In each row, we report per-worker average monthly amounts in HUF for workers aged 55 and above. Row (1) reports the direct cost defined as the tax cut multiplied by the employment rate of the treatment group. Row (2) reports the tax cut received by workers based on the wage effect results reported in Table 6. Row (3) reports the benefits that non-employed individuals who become employed would have received based on the estimated employment effect of the reform and the average unemployment benefit amount. Row (4) reports the additional net wages received by non-employed individuals who become employed based on the estimated employment effect by wage categories. Row (5) reports the additional tax revenue defined as the total estimated income tax and social security contributions paid for workers who become employed. The net cost of the tax cut is the direct cost (row 1) minus the cost saving coming from lower benefits (row 3) and the higher tax revenue (row 5). The willingness to pay from the worker perspective is the wage increase incumbent workers experience (row 2) and earnings of the newly employed (row 4) minus the lost benefits (row 3). The willingness to pay from the worker and firm perspective is the direct cost (row 1), earnings of the newly employed (row 4) minus the lost benefits (row 3). The marginal value of public fund (MVPF) is the ratio of willingness to pay and the net cost. We report MVPF calculations for workers at all firms (column 1), and also separately for workers at low-productivity firms (column 2) and at high-productivity firms (column 3).

Appendix

A The Effect of Tax Cuts in Search Models

In this section we illustrate the impact of payroll taxes in the presence of search frictions. We introduce a tax cut in a framework with random search, heterogeneous firms, and sequential bargaining on wages (Postel-Vinay and Robin, 2002). We study how the tax cut affects employment, wages, and the composition of job types in equilibrium. Since our goal is illustration we make several simplifying assumptions that can be (and have been) relaxed in the literature without fundamentally affecting our conclusions. In particular, we abstract away from worker heterogeneity and assume that job search is exogenous.

A.1 Setup

Firms are heterogeneous, characterized by productivity $y \in [y_{min}, y_{max}]$, with continuous cumulative distribution function $\Psi(\cdot)$. A job offer is a draw of a firm productivity from the vacancy distribution $\Gamma(\cdot)$ with probability distribution function $\gamma(\cdot)$. For simplicity, we assume that the output of a y-productivity firm is also y.

Workers are homogeneous. Workers are either unemployed or employed. If unemployed, they receive leisure of value b (with $b < y_{min}$) and search for jobs with probability one. If employed, they receive wage w, search for a new job with probability $s \in [0, 1]$ and can separate from their job exogenously with probability $\delta \in [0, 1]$.

Firms can advertise vacancies at the increasing and convex cost $\kappa(\cdot)$. Job market tightness is the ratio between total vacancies (v) and total search effort by the unemployed (u) and employed ($(1-\delta)(1-u)$):

$$\theta = \frac{v}{u + s(1-\delta)(1-u)}. \tag{A.1}$$

The probability for a searching worker of locating an open vacancy is $\phi(\theta)$, increasing in θ. The probability for an open vacancy of meeting a worker who is searching for jobs is $\phi(\theta)/\theta$, decreasing in θ.

Wage setting is as in the sequential auction model of Postel-Vinay and Robin (2002). When an employed worker contacts an open vacancy, the prospective poacher and the incumbent employer observe each other's match qualities with the worker, and engage in Bertrand competition over contracts. The worker chooses the contract that delivers the larger value. For simplicity, we also assume that all the bargaining power is at the firms and so they are able to extract all rents from the workers.[33]

[33]It is straightforward to introduce some bargaining power of the worker in the model. Nevertheless, empirical studies usually find that bargaining power is quite small and so we do not miss a lot by abstracting away from that.

A.2 Bellman Equations

Using that firms extract all the rents from unemployed workers, making them indifferent between working and remaining unemployed, the value of unemployment satisfies

$$V_u = b + \beta V_u, \tag{A.2}$$

where β is the discount factor. Thus,

$$V_u = \frac{b}{1-\beta}. \tag{A.3}$$

The joint value to the firm and the worker from a match is:

$$V(y,\tau) = y + \tau + \delta\beta V_u + (1-\delta)\beta V(y,\tau), \tag{A.4}$$

where τ is the tax cut. Note, that the joint value of the match does not include the possibility of receiving an outside offer. This is the consequence of the assumption that all the bargaining power is at the firms and so any new offers will not benefit the worker and the current firm.[34] After rearrangement:

$$(1-\beta+\delta\beta)V(y,\tau) = y + \tau + \frac{\delta\beta b}{1-\beta}. \tag{A.5}$$

Since all the joint surplus will be captured by the firms, the value of posting vacancies will be the following:

$$V_v(y,\tau) = \max_{\nu}\Bigg\{ -\kappa(\nu) + \beta\nu\frac{\phi(\theta)}{\theta}\Bigg(P(u)\Big[V(y,\tau) - V_u\Big] + \\ + (1-P(u))\int_{y_{min}}^{y}\Big[V(y,\tau) - V(y',\tau)\Big]d\Gamma(y')\Bigg)\Bigg\}, \tag{A.6}$$

where $P(u)$ is the probability that a randomly drawn job applicant is unemployed:

$$P(u) = \frac{u}{u + (1-\delta)s(1-u)}, \tag{A.7}$$

and $\Gamma(y)$ is the sampling distribution of the vacancy pool.[35] That latter is the recruitment intensity weighted firm-type distribution:

[34] In the presence of bargaining power the joint value would look as follows:
$V(y,\tau) = y + \tau + \delta\beta V_u + (1-\delta)\beta V(y,\tau) + \lambda(1-\delta)\beta s\phi(\theta)\int_y^{y_{max}}(V(y',\tau) - V(y,\tau))d\Gamma(y')$, where λ is the workers' bargaining power. Our derivation and results would hold in the presence of some bargaining power of workers, but the notation would be more complicated.

[35] As we describe later, firms set wages to ensure that they realize all the joint surplus. In particular, the initial wage agreed at the match will take into account future wage growth coming from renegotiation and poaching.

$$\Gamma(y) = \frac{\int_{y_{min}}^{y} \nu(y',\tau) d\Psi(y')}{\int_{y_{min}}^{y_{max}} \nu(y',\tau) d\Psi(y')}. \tag{A.8}$$

Furthermore, the total amount of vacancies is $v = \int_{y_{min}}^{y_{max}} \nu(y',\tau) d\Psi(y')$. Using equation (A.5), equation (A.6) can be rewritten:

$$V_v(y,\tau) = \max_{\nu} \Bigg\{ -\kappa(\nu) + \beta\nu \frac{\phi(\theta)}{\theta} \Bigg(P(u) \Bigg[\frac{y+\tau}{1-\beta+\delta\beta} - \frac{1-\delta\beta}{1-\beta+\delta\beta} \frac{b}{1-\beta} \Bigg] + \\ + (1-P(u)) \int_{y_{min}}^{y} \Bigg[\frac{y-y'}{1-\beta+\delta\beta} \Bigg] d\Gamma(y') \Bigg) \Bigg\}. \tag{A.9}$$

A.3 Equilibrium

The cumulative distribution of employment is $L(\cdot)$, with:

$$L(y) = (1-\delta) \Big[1 - s\phi(\theta)(1-\Gamma(y)) \Big] L(y) + \phi(\theta)\Gamma(y)u, \tag{A.10}$$

where the first term on the right-hand side captures that part of employment that survives the exogeneous separation $(1-\delta)$ and is not poached by higher productivity firms $(1 - s\phi(\theta)(1-\Gamma(y)))$, whereas the second term $(\phi(\theta)\Gamma(y)u)$ captures the employment arriving from unemployment. Employment at firms with productivity y is the derivative of $L(y)$ with respect to y:

$$l(y) = (1-\delta) \Bigg[\Big[1 - s\phi(\theta)(1-\Gamma(y)) \Big] l(y) + s\phi(\theta)\gamma(y) \int_{y_{min}}^{y} l(y')dy' \Bigg] + \phi(\theta)\gamma(y)u. \tag{A.11}$$

The steady-state rate of unemployment is:

$$u = (1-\phi(\theta))u + \delta(1-u). \tag{A.12}$$

Thus,

$$u = \frac{\delta}{\delta + \phi(\theta)}. \tag{A.13}$$

Firms maximize their profit and so they post vacancies up to the point where the marginal value of a vacancy is zero.

$$\kappa'(\nu(y,\tau)) = \beta \frac{\phi(\theta)}{\theta} \Bigg(P(u) \Bigg[\frac{y+\tau}{1-\beta+\delta\beta} - \frac{1-\delta\beta}{1-\beta+\delta\beta} \frac{b}{1-\beta} \Bigg] + \\ + (1-P(u)) \int_{y_{min}}^{y} \Bigg[\frac{y-y'}{1-\beta+\delta\beta} \Bigg] d\Gamma(y') \Bigg). \tag{A.14}$$

The equilibrium solution of θ and $\Gamma(y)$ satisfies equations (A.1), (A.7), (A.8), (A.10), (A.13) and (A.14).

A.4 Wage

This section is based on Postel-Vinay and Robin (2002).

Contracts can be renegotiated by mutual consent. If a worker of a firm with productivity y receives an outside offer from a firm with productivity y' then three events can occur:

1. *Worker is poached:* The poaching firm wins the competition over the incumbent firm if $y' > y$ and the wage increases.

2. *Wage renegotiation:* If the worker meets a firm that can deliver greater value than the current contract, but is less productive than the current firm, the contract is renegotiated and the worker stays.

3. *No change:* If neither of the above two conditions is met, the worker stays at the current firm and the wage remains unchanged.

The value of employment at firm of type y and at wage w is $V_e(w, y)$. A worker moves to a potentially better match with a firm type-y' if it offers at least the wage $\omega(y, y', \tau)$ defined by:

$$V_e(\omega(y, y', \tau), y) = V_e(y + \tau, y). \tag{A.15}$$

Lower offers are outbid by the type-y incumbent firm.

The Bellman equation for the value of employment is the following (corresponding to equation (16) of Postel-Vinay and Robin, 2002):

$$\underbrace{\left(\delta + \frac{1-\beta}{\beta} + s\phi(\theta)(1 - \Gamma(q(w, y, \tau)))\right)}_{\text{Separation rate + discount rate + prob. of renegotiation or poaching}} \cdot \underbrace{V_e(w, y)}_{\text{Value of employment}} =$$

$$= \underbrace{U(w)}_{\text{Flow utility from wage}} + \underbrace{s\phi(\theta) \int_{q(w,y,\tau)}^{y} V_e(x + \tau, x) d\Gamma(x)}_{\text{Expected value from renegotiation}} +$$

$$+ \underbrace{s\phi(\theta)(1 - \Gamma(y))V_e(y + \tau, y)}_{\text{Expected value from poaching}} + \underbrace{\delta V_u}_{\text{Expected value from job loss}}, \tag{A.16}$$

where $q(w, y, \tau)$ is the threshold productivity, defined by $\omega(q(w, y, \tau), y, \tau) = w$. In other words, $q(w, y, \tau)$ is the lowest productivity level y' such that competition between a type-y and a type-y' firm raises the wage above w (which equals y_{min} if $w = b$). $U(w)$ is the instantaneous utility flow from wage w. The second term on the right hand side of equation (A.16) captures the employment value after a wage increase at the current firm (reflecting that the incumbent firm needs to match the offer of the competitor), whereas the third term captures the value of employment at a higher productivity firm (after being poached, using equation (A.15)).

Assuming CRRA utility function with rate of relative risk aversion ζ ($U(x) = x^{1-\zeta}$), where $0 \leq \zeta < 1$, we can derive an expression for wages, following Appendix A.1. of Postel-Vinay and Robin (2002) and incorporating the tax cut (τ) into their model:

$$\ln \omega(y, y', \tau) = \frac{1}{1-\zeta} \ln \Big[(y+\tau)^{1-\zeta} - \frac{(1-\zeta) s \phi(\theta)}{\frac{1-\beta}{\beta} + \delta} \int_y^{y'} (1 - \Gamma(x))(x+\tau)^{-\zeta} dx \Big]. \quad \text{(A.17)}$$

The wage of workers who have not been subject to wage bargaining yet is:

$$\ln \omega_u(y, \tau) = \frac{1}{1-\zeta} \ln \Big[b^{1-\zeta} - \frac{(1-\zeta) s \phi(\theta)}{\frac{1-\beta}{\beta} + \delta} \int_{y_{min}}^{y} (1 - \Gamma(x))(x+\tau)^{-\zeta} dx \Big]. \quad \text{(A.18)}$$

The negative terms in the above two equations capture the option value of employment: workers accept lower wages to work at more productive firms because workers trade a lower wage now for increased chances of higher wages tomorrow (Postel-Vinay and Robin, 2002).

The equilibrium within-firm distribution of wages has two components, the employer effect (y) and a random effect (q) that characterizes the most recent wage mobility. We denote with $\tilde{G}(q|y)$ the cumulative distribution function of the conditional distribution of bargaining position within the pool of workers within type-y firms.

$$G(w|y) = \tilde{G}(q|y) = \frac{(1 + \Upsilon(1 - \Gamma(y)))^2}{(1 + \Upsilon(1 - \Gamma(q)))^2} \quad \text{(A.19)}$$

for all $q \in \{b\} \cup [y_{min}, y]$, where $\Upsilon = \phi(\theta) s / \delta$. Equation (A.19) is derived following the derivation on page 2341 of Postel-Vinay and Robin (2002).

A.5 Effects of the Tax Cut

First, let us point out that hiring intensity increases in firm productivity y because both the output and the acceptance rate increase with y in the right hand side of equation (A.14). Using that $\kappa(\cdot)$ is increasing in ν leads us to Result 1.

Result 1 *Hiring intensity is increasing in firm productivity:* $\dfrac{\partial \nu(y, \tau)}{\partial y} > 0$.

Our next result follows directly from equation (A.14), using that $\kappa(\cdot)$ is increasing and convex in the amount of vacancies.

Result 2 *The partial effect of the tax cut (an increase in τ holding u constant) leads to more vacancy posting at all firms, formally* $\dfrac{\partial \nu(y, \tau)}{\partial \tau} > 0$.

An immediate consequence of Result 2 is that increased vacancy posting leads to tighter labor market. This itself lowers the equilibrium unemployment rate as it is shown in equation (A.13) (remember, $\phi(\theta)$ increases in θ).

Furthermore, equation (A.7) can be rewritten as:

$$P(u) = \frac{\delta}{\delta + (1-\delta)s\phi(\theta)}. \tag{A.20}$$

and so $P(u)$ will decrease as a consequence of the tax cut.

Note that the decrease in $P(u)$ has a feedback equilibrium effect on vacancy posting as it affects the right hand side of (A.14). Since the maximum value firms are willing to offer, $V(y', \tau)$, must be at least as high as the value of unemployment V_u, we have $V(y', \tau) \geq V_u$ for all y'. Notice that this implies that the left hand side of (A.14) will decrease, and so will vacancy posting, since $\kappa(\cdot)$ is increasing in ν. Therefore, the equilibrium effect will dampen to some extent the immediate effect of the tax cut on vacancy posting. Nevertheless, we can rule out that the feedback effect is large enough to fully offset the initial increase in vacancy posting. To see that, assume the opposite is true and the feedback effect fully offsets the initial increase in vacancy posting. In such a situation there would be no feedback effect to begin with, leading to a contradiction.

As a consequence, the following result will be true:

Result 3 *The equilibrium unemployment rate (u) and the probability that a randomly drawn applicant is unemployed ($P(u)$) decrease in τ.*

Now we turn to discussing the heterogeneity in response to the tax cut. Firms' optimality condition – equation (A.14) – implies that the change in the right hand side is the same for all type of firms in the absence of any equilibrium effects (i.e., unemployment rate is constant). Based on the convexity of the vacancy cost function $\kappa(\cdot)$ and using that $\nu(y, \tau)$ increases in y, it follows that the increase in vacancies ($\nu(y, \tau)$) is smaller at higher values of y.

To derive this result formally, we introduce the notation for the inverse of the first derivative of the cost function $\chi(\cdot) := (\kappa')^{-1}(\cdot)$. Using this notation, we can rewrite equation (A.14) as:

$$\nu(y,\tau) = \chi\Bigg(\beta\frac{\phi(\theta)}{\theta}\Bigg(P(u)\left[\frac{y+\tau}{1-\beta+\delta\beta} - \frac{1-\delta\beta}{1-\beta+\delta\beta}\frac{b}{1-\beta}\right] + \\ + (1-P(u))\int_{y_{min}}^{y}\left[\frac{y-y'}{1-\beta+\delta\beta}\right]d\Gamma(y')\Bigg)\Bigg). \tag{A.21}$$

It follows that

$$\frac{\partial^2\nu(y,\tau)}{\partial\tau\partial y} = \chi''\Bigg(\beta\frac{\phi(\theta)}{\theta}\Bigg(P(u)\left[\frac{y+\tau}{1-\beta+\delta\beta} - \frac{1-\delta\beta}{1-\beta+\delta\beta}\frac{b}{1-\beta}\right] + \\ + (1-P(u))\int_{y_{min}}^{y}\left[\frac{y-y'}{1-\beta+\delta\beta}\right]d\Gamma(y')\Bigg)\Bigg)\cdot\beta\frac{\phi(\theta)}{\theta}P(u)\frac{1}{1-\beta+\delta\beta}. \tag{A.22}$$

In this formula the terms after the $h''(\cdot)$ expression are positive. Thus the sign of $\chi''(\cdot)$ needs

to be determined:

$$\chi''(x) = \left((\kappa')^{-1}\right)''(x) = \left(\frac{1}{\kappa'(z)}\right)' = -\kappa''(z) < 0, \tag{A.23}$$

where $z = (\kappa')^{-1}(x)$ and in the last step we used the convexity of the $\kappa(\cdot)$ function. This leads us to Result 4.

Result 4 *The partial effect of the tax cut on vacancy posting decreases with firm productivity, formally* $\dfrac{\partial^2 \nu(y,\tau)}{\partial \tau \partial y} < 0$.

Result 4 implies that the partial effect of the policy is that employment increases more at low-productivity firms than at high-productivity firms. However, some of these effects will be offset by the decrease in the unemployment rate. The lower unemployment rate affects more negatively the low-productivity firms than the high-productivity ones (this can be seen from equation (A.6)). Unfortunately, it is not possible to derive analytically the equilibrium effect of the tax cut on the employment rate. In Section A.6, we provide simulation-based evidence that the equilibrium effects are small in practice and the derived partial effects dominate.

Turning to the impact of the tax cut on wages, we use equation (A.17) to derive the partial effect of the tax cut on the wage of workers who have been poached or had a wage bargaining. To simplify notation, let's use the shorthand notation $\Omega = \Big[(y+\tau)^{1-\zeta} - \frac{(1-\zeta)s\phi(\theta)}{\frac{1-\beta}{\beta}+\delta}\int_y^{y'}(1-\Gamma(x))(x+\tau)^{-\zeta}dx\Big]$.

$$\frac{\partial \ln \omega(y,y',\tau)}{\partial y'} = \frac{1}{1-\zeta}\frac{1}{\Omega}\left[-\frac{(1-\zeta)s\phi(\theta)}{\frac{1-\beta}{\beta}+\delta}(1-\Gamma(x))(y'+\tau)^{-\zeta}\right]. \tag{A.24}$$

From this, we derive how the partial effect of the tax cut varies with firm productivity:

$$\frac{\partial^2 \ln \omega(y,y',\tau)}{\partial \tau \partial y'} = \frac{1}{1-\zeta}\frac{1}{\Omega^2}\frac{(1-\zeta)s\phi(\theta)}{\frac{1-\beta}{\beta}+\delta}\left[\Omega\zeta(1-\Gamma(x))(y'+\tau)^{-\zeta-1} + (1-\Gamma(x))(y'+\tau)^{-\zeta}\frac{\partial \Omega}{\partial \tau}\right], \tag{A.25}$$

which is clearly non-negative (positive except for at $y' = y_{max}$, where it reaches zero), using that $0 \leq \zeta < 1$. Note also that based on (A.17), the partial effect of the tax cut is positive at all productivity levels. This leads us to Result 5.

Result 5 *The partial effect of the tax cut on wages is positive for workers who already had a wage bargaining or have been poached:* $\dfrac{\partial \ln \omega(y,y',\tau)}{\partial \tau} > 0$. *This partial effect increases with firm productivity:* $\dfrac{\partial^2 \ln \omega(y,y',\tau)}{\partial \tau \partial y'} > 0$.

The wages at the lowest productivity firm are determined by equation (A.18), because once an employer receives an alternative offer she is the poached by the competing (more

productive) firm. As the option value is zero at the lowest productivity firms, the partial effect of the tax cut on wages is also zero for workers at the lowest productivity firms.

At firms above the lowest productivity, the partial effect of the tax cut on the wage of workers who had not had a wage bargaining is positive and increasing in firm productivity through the impact of the tax cut on the option value (the same reasoning applies as under equations (A.24) and (A.25)). In the absence of equilibrium effects, the ratio of workers arriving from unemployment is constant.

Result 6 *The partial effect of the tax cut on wages of workers arriving from unemployment (who have not had a wage bargaining) is zero at the lowest productivity firms and increasing with higher productivity levels:* $\frac{\partial^2 \ln \omega_u(y,\tau)}{\partial \tau \partial y} = 0$ *if* $y = y_{min}$ *and* $\frac{\partial^2 \ln \omega_u(y,\tau)}{\partial \tau \partial y} > 0$ *if* $y > y_{min}$.

The equilibrium effect of the tax cut on wages cannot be derived analytically. First, its positive effect on $\phi(\theta)$ increases the negative wage implications of the option value in equations (A.17) and (A.18). On the other hand, we know from Result 4 that the tax cut shifts the distribution of vacancies towards less productive firms, thus $(1-\Gamma)$ decreases as a consequence of the tax cut but this decreasing effect varies with firm productivity.

Note also that the wages of new entrants are driven by equation (A.18). Intuitively, younger workers enter the labor market as non-employed, thus, essentially, poaching and wage renegotiation are not relevant for them. This means that new entrants cannot use current wages as an outside option to achieve full surplus extraction – instead, they accept any offer (as the reservation threshold of firm productivity is zero), and can start bargaining over wages once employed. Also, the firm heterogeneity in the employment effects of the tax cut is smaller if all workers are new entrants since then low- and high-productivity firms hire from unemployment to the same extent, thus low-productivity firms no longer benefit disproportionately more from the tax cut.

A.6 Simulations

In this section, we provide simulation results for the effects of the tax cut, taking into account the equilibrium effects in addition to the analytically analyzed partial effects. We quantify the impact of a tax cut that is 6% of the average wage in the economy. Applying parameter values and functional form assumptions usually applied in the literature we find that employment increases by 3.7% at low-productivity firms, and by 0.8% at high-productivity ones. At the same time, wages increase by 0.8% at low-productivity firms, implying a close to a zero pass-through rate, while wages increase by 2.9% at high-productivity firms, implying a 48% average pass-through rate.

The functional forms used in the simulations are the following. The cost function, based on Bagger and Lentz (2019) is:

$$\kappa(v(y,\tau)) = \frac{v(y,\tau)^{(1+1/c_v)}}{1+1/c_v},$$

where $c_v > 0$ determines curvature. The job-finding rate is similar to Moscarini and Postel-Vinay (2018): $\phi(\theta) = A\theta^{\alpha}$.

The parameters used in the simulations are the following:

- The tax cut is 6% of the average wage without tax: $\tau = \bar{w}_0 \times 0.06$.
- y has $Pareto(\lambda, y_{min})$ distribution, where λ is the scaling parameter and y_{min} is a drift that shifts the original Pareto distribution, such that the lower bound is equal to y_{min}. During the simulations $\lambda = 1.25$ and $y_{min} = 1000$.
- $\zeta = 0.95$, which is the exponent in the CRRA utility function, implying close to log-utility. The simulation results are robust to different ζ values. It has primarily an effect on the wage change.
- $A = 1/4$, to calibrate an unemployment rate of around 20%.
- $\alpha = 1/2$, similar to Moscarini and Postel-Vinay (2018).
- The employment-to employment transition rate (EE) is 0.041, which is in line with the empirical data for Hungary (12-month transition rate between employers among the continuously working older workers). The searching intensity (s) is a direct mapping of this parameter, see the derivations in Moscarini and Postel-Vinay (2018). To obtain s, we solve for:

$$\phi(\theta)(1-\delta)\delta s \int_0^1 \frac{1-x}{\delta + (1-\delta)s\phi(\theta)x} dx = EE. \tag{A.26}$$

- $\beta = 0.95$, which matches the monthly value of $0.95^{1/12}$ by Moscarini and Postel-Vinay (2018).
- $b = y_{min} = 1000$, thus the workers' outside option is the same as the output of the lowest productivity firm.
- $c_v = 0.006$, similarly to Bagger and Lentz (2019).
- Job destruction rate $\delta = 0.1$, corresponding to the 12-month separation rate observed in the data for Hungary.

Table A1 displays the simulated impact of the tax cut on unemployment, job market tightness and job finding rate. The rate of unemployment decreases by 1.7 percentage points form its baseline rate of 22.3%. At the same time, both job market tightness and job finding rate increase as a consequence of the tax cut.

Appendix Table A1: Steady-State Parameters

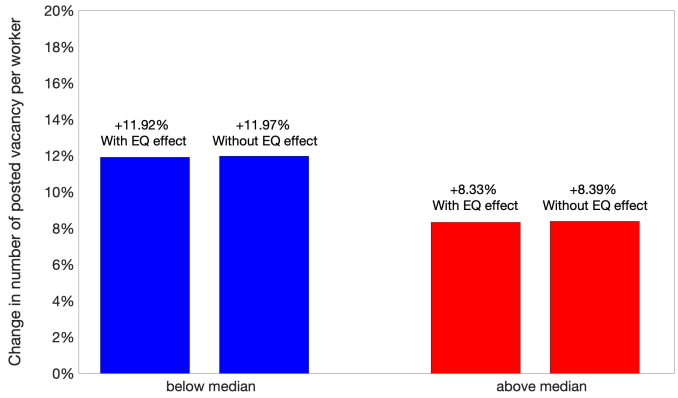
	(1)	(2)	(3)
Tax cut	0%	6%	Δ (15%)
Unemployment	0.223	0.206	-0.017
Job market tightness (θ)	1.935	2.380	0.445
Job finding rate	0.348	0.386	0.038

Note: Table shows the steady-state unemployment rate (defined by equation (A.13)), job market tightness (θ), defined by equation (A.1) and job finding rate ($\phi(\theta)$).

Figure A1 shows that the tax cut increases the vacancy posting activities of firms. In line with our theoretical considerations, the impact is bigger at low-productivity firms. At low-productivity firms, the vacancies posted increase by 12%, whereas at more productive firms only by 8.3%. These simulated impacts are slightly higher if we ignore the equilibrium effects in the model. Figure A2 shows that as a consequence of the increased vacancy posting activities, employment at less productive firms increases by 3.7%, while employment at more productive firms increase by 0.8%.

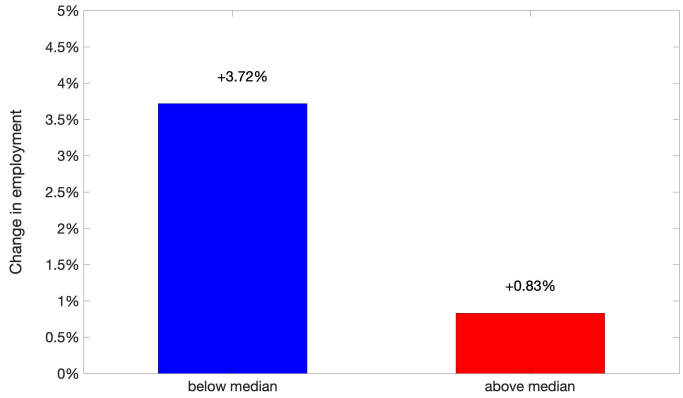
Turning to wages (Figure A3), the wage impact of the tax cut for workers who were not employed the previous period is essentially zero, while it is 2.3% for the rest of the workers ("incumbents"). Finally, among incumbent workers, the wage effect is small (0.8%) at low-productivity firms, whereas it is larger (3%) at high-productivity firms (Figure A4).

Appendix Figure A1: Simulation Results: Vacancies



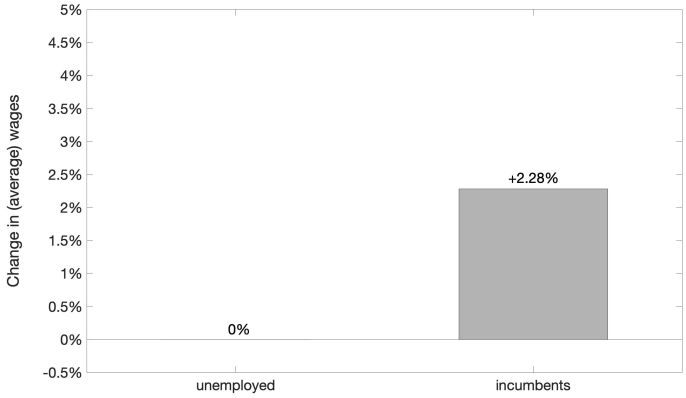
Note: Figure shows the simulated effect of a tax cut that is 6% of the average wage in the economy. Figure shows the impact of the tax cut on the number of posted vacancies per worker by productivity category of the employer (below- or above-median productivity). For each productivity category, the left bars show the impact with equilibrium (EQ) effects, the right bars show the impact without equilibrium effects.

Appendix Figure A2: Simulation Results: Employment



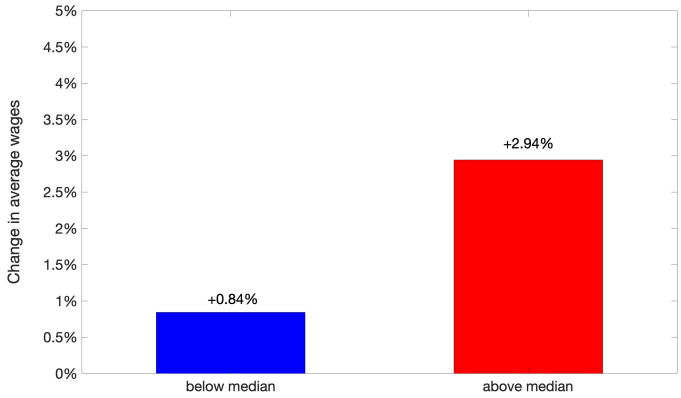
Note: Figure shows the simulated effect of a tax cut that is 6% of the average wage in the economy. Figure shows the impact of the tax cut on employment in percentage terms by productivity category of the employer (below- or above-median productivity).

Appendix Figure A3: Simulation Results: Wage by Previous Labor Force Status



Note: Figure shows the simulated effect of a tax cut that is 6% of the average wage in the economy. Figure shows the impact of the tax cut on the wage of workers who were not employed ("unemployed") or were employed ("incumbents") the previous period. The latter group includes workers who earn the first wage since unemployment and also those who already had a wage bargaining.

Appendix Figure A4: Simulation Results: Wage of Incumbent Workers

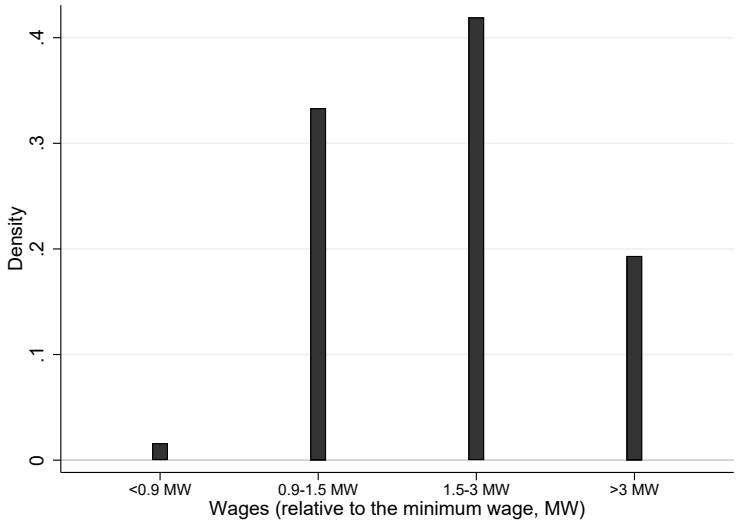


Note: Figure shows the simulated effect of a tax cut that is 6% of the average wage in the economy. Figure shows the impact of the tax cut on the wage of incumbent workers by productivity category of the current employer (below- or above-median productivity). The group of incumbent workers consists of workers who earn the first wage since unemployment but were already working the previous period and workers who already had a wage bargaining.

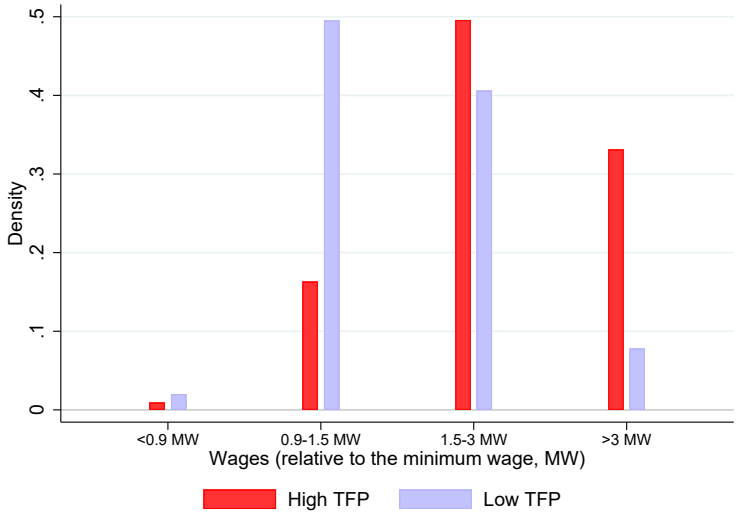
B Additional Figures and Tables

Appendix Figure B1: The Wage Distribution of Private Sector Workers

(a) All



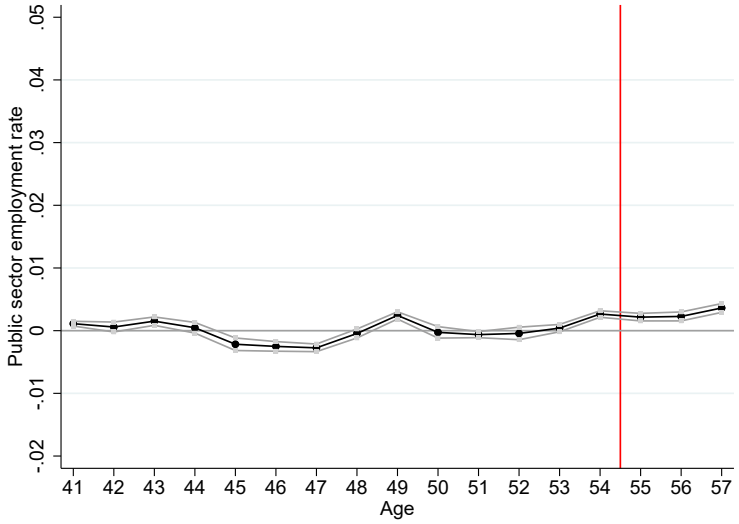
(b) By TFP



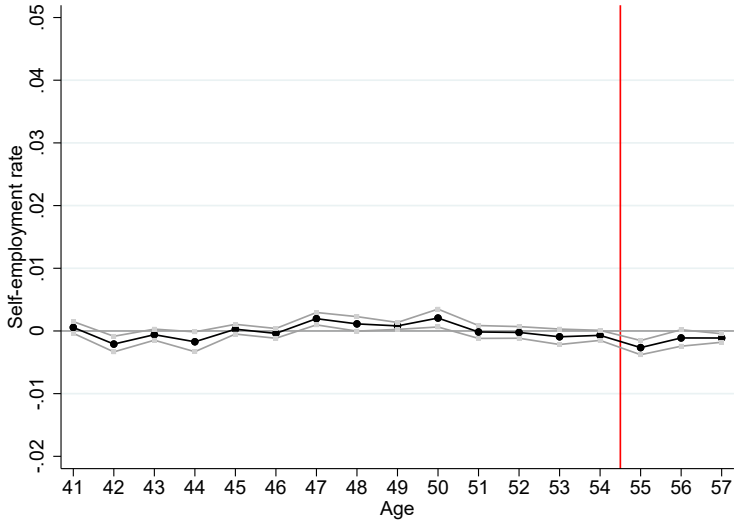
Note: Figure shows the density of workers aged 52-57 working at private sector companies (our main sample). We plot wage categories relative to the minimum wage. Panel (a) shows the distribution at all private sector firms. Panel (b) shows the distribution separately for workers at high-productivity (above-median TFP) firms (in red) and at low-productivity (below-median TFP) firms (in blue).

Appendix Figure B2: Change in Employment in Sectors Unaffected by the Tax Cut

(a) Public Sector Employment Rate

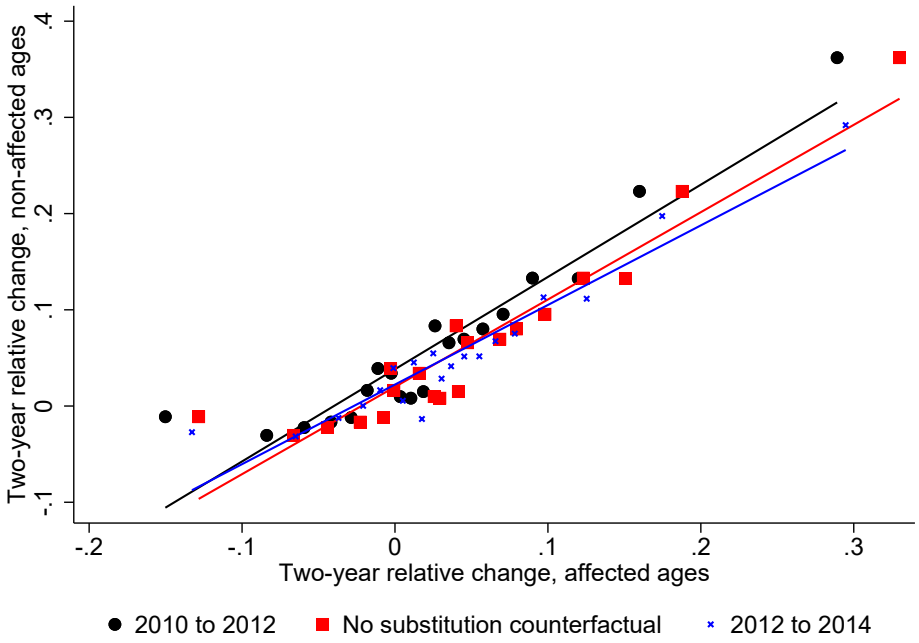


(b) Self-Employment Rate



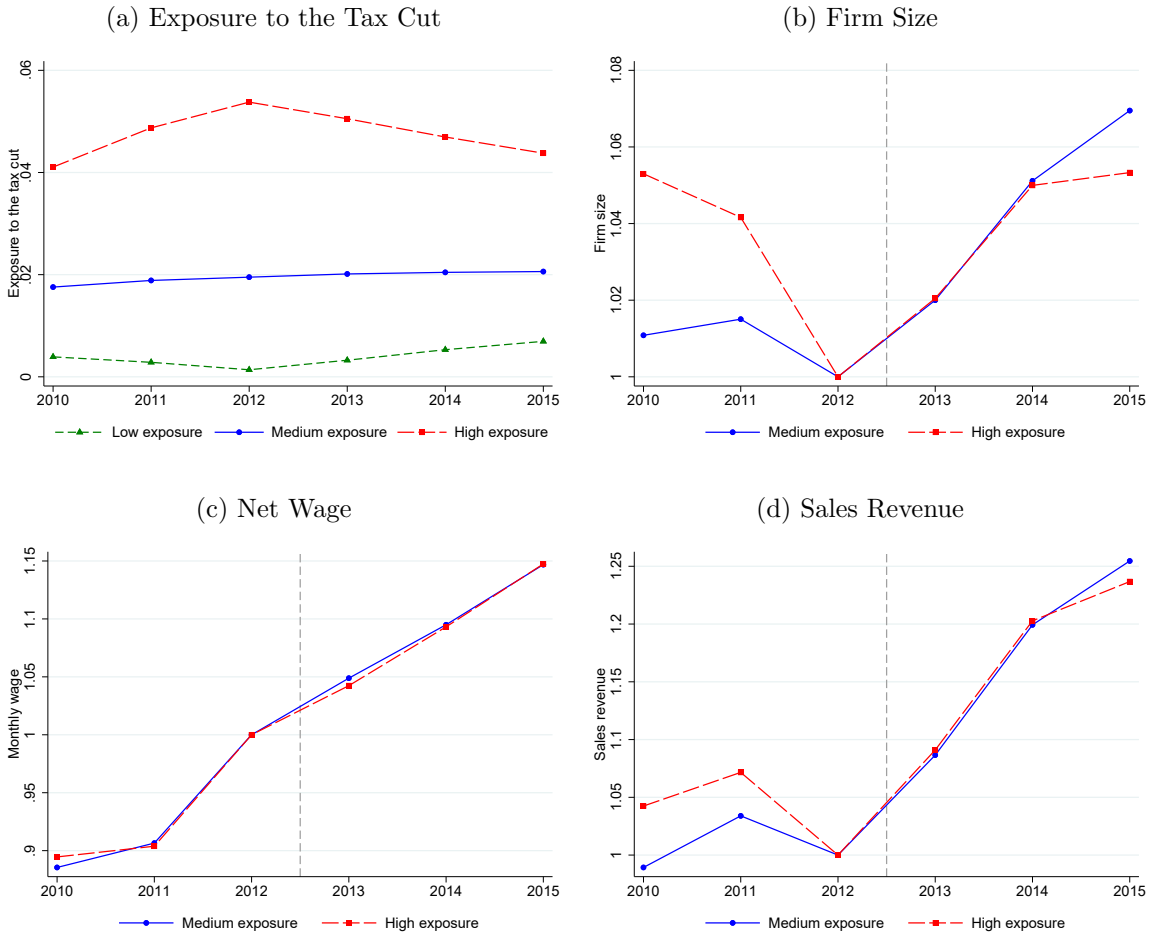
Note: Figure shows the public sector employment rate in Panel (a) and the self-employment rate in Panel (b) by age before and after the introduction of the age-specific payroll tax cut affecting only private sector firms. The figure shows the difference in employment rates between years 2012 and 2013-2015 relative to the average change between ages 41 and 54, with the 95% confidence interval (standard errors clustered at the age × period level). The vertical red line shows the age threshold where the tax cut was effective for private sector workers. At the same time, nothing was changed at that age threshold for public sector workers or the self-employed.

Appendix Figure B3: Relationship between Firm-Level Employment Change in Affected Age Groups and Non-affected Age Groups



Note: Figure shows the relationship between firm-level two-year employment change in affected age groups and non-affected age groups before the introduction of the payroll tax cut (2010 to 2012, in black) and after the introduction of the payroll tax cut (2012 to 2014, in blue). On the x-axis, we indicate the two-year change from year t to year $t+2$ in the number of workers aged up to 24 or at least 55 (affected ages) relative to the observed firm size in year t. On the y-axis, we indicate the same two-year relative change in the number of workers aged 25-54 (unaffacted ages). We exclude firms with less than 10 workers and firms that are not in the sample throughout years 2010-2014. We show a binned scatterplot of the observations with a linear fitted regression line. The black dots and line refer to relative change from 2010 to 2012 (i.e., before the introduction of the tax cut). The blue dots and line refer to relative change from 2012 to 2014 (with the tax cut being introduced in 2013). The red dots and line correspond to a counterfactual scenario where we increase 2010-2012 employment changes in the affected age groups by 9.4%, which is our benchmark estimate on the overall employment change, while employment changes in the unaffected ages are left as is. This later estimate, therefore, shows the relationship that would emerge if the 2010-2012 employment in the affected age groups increased as estimated, and firms did not substitute unaffected workers with affected workers by cutting their employment.

Appendix Figure B4: Firm-level Effects of Payroll Tax Cuts



Note: Figure replicates the basic results of Saez, Schoefer and Seim (2019). Using 2012 data, we calculate the firm-level exposure to the tax cut defined as the total tax cut based on workers aged 55 and above at the firm relative to the total payroll of the firm. We calculate the quartiles of the exposure, excluding firms with zero exposure, and group firms into three categories. "Low exposure" firms have either zero tax cut or belong to the bottom quartile. "Medium exposure" firms belong to the middle two quartiles. "High exposure" firms belong to the the top quartile. We compare the evolution of various outcomes of the firms in these groups, focusing on the medium and high exposure groups. Panel (a) shows the average exposure to the tax cut. Panel (b) shows firm size. Panel (c) shows average net wage. Panel (d) shows sales revenue.

Appendix Table B1: Employment Rate in the Administrative Data and in the Labor Force Survey

	(1) Administrative data	(2) Labor Force Survey
Panel A: Private and public sector		
Including self-employment	60.1%	61.6%
Excluding self-employment	49.4%	51.8%
Panel B: Private sector (excluding self-employment)		
All private sector firms	43.1%	
Double-entry bookkeeping firms	37.5%	
Double-entry bookkeeping firms with at most 10,000 employees	35.5%	

Note: Table reports employment rates in the non-retired population of men aged 52-57 in 2012. Column (1) reports employment rates based on the linked employer-employee administrative data used in this paper. Column (2) reports employment rates based on the Labor Force Survey (LFS) of the Hungarian Central Statistical Office, which is the European equivalent of the Current Population Survey (CPS). Panel A shows employment rates in the private and public sectors with and without the self-employed. Panel B shows private sector employment in all firms, double-entry bookkeeping firms, and double-entry bookkeeping firms with at most 10,000 employees. It displays statistics only based on the administrative data because civil servants and the type of the firm cannot be identified in the LFS. The employment category in the last row corresponds to the employment definition we use in this paper.

Appendix Table B2: Employment Effects of the Tax Cut for All Private Sector Firms and for Firms with Double-entry Bookkeeping

	(1)	(2)	(3)
		Employment	
	All firms	Low TFP	High TFP
Panel A: Double-entry bookkeeping firms,	0.0053***	0.0053***	-0.0001
excluding firms with more than 10,000 workers	[0.0005]	[0.0005]	[0.0004]
	⟨0.330⟩	⟨0.167⟩	⟨0.163⟩
Panel B: All firms, including single-entry bookkeping	0.0096***	0.0094***	0.0003
firms and firms with more than 10,000 workers	[0.0006]	[0.0006]	[0.0004]
	⟨0.409⟩	⟨0.227⟩	⟨0.181⟩

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: Table shows difference-in-differences estimates of the impact of the payroll tax cut on private sector employment for all firms (column 1) and separately for below-median (column 2) and above-median (column 3) TFP firms. In particular, we report the β coefficient from regression equation (9) with the outcome variable being employed at a private sector firm (column 1), at a private sector firm with below-median productivity (column 2) and at a private sector firm with above-median productivity (column 3). In angle brackets we report the mean of these outcome variables in May 2012—the probability of being employed in a given subgroup and type of firm. The β coefficient compares the change in employment among the 55 to 57 age group that was affected by the payroll tax cut relative to the change in employment among the 52 to 54 age group that was not affected by the tax cut. In Panel A, we report the results for the baseline category of private sector employment (excluding firms with more than 10,000 workers). In Panel B, we report the results for all firms, assuming that all single-entry bookkeping firms (for which firms the TFP is not observed) are below-median TFP firms. Standard errors are reported in brackets, clustered at the age $\times$ period level. ($N = 9,003,984$ individual-months)

Appendix Table B3: Employment Effects of the Tax Cut: Extensive Margin Employment Decisions

	(1) All firms	(2) Low TFP	(3) High TFP
Panel A: Change in the probability of employment			
— $After \times Treated$	0.0054***	0.0053***	0.0001
	[0.0005]	[0.0005]	[0.0004]
Panel B: Percent change in employment			
—Employment without tax cut	0.342	0.176	0.176
—Employment with tax cut	0.347	0.182	0.182
—Percent change in employment	1.58%	3.00%	0.05%
Panel C: Percent change in labor cost $(1+\tau_{ss})$			
—Labor cost without tax cut	1.27	1.26	1.28
—Labor cost with tax cut	1.20	1.18	1.22
—Percent change in labor cost	-5.27%	-6.02%	-4.45%
Panel D: Implied elasticity (Panel B/Panel C)			
—Elasticity	-0.30	-0.50	-0.01
	[0.03]	[0.05]	[0.06]

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: Table shows the employment effect of the tax cut as in Table 2 with the difference that we focus on extensive margin employment decisions (whether to work or not) without taking into account working hours. Panel A of the table shows difference-in-differences estimates of the impact of the payroll tax cut on private sector employment for all firms (column 1) and separately for below-median (column 2) and above-median (column 3) TFP firms in Panel A. In particular, we report the β coefficient from regression equation (9) with the outcome variable being employed at a private sector firm (column 1), at a private sector firm with below-median productivity (column 2), and at a private sector firm with above-median productivity (column 3). The β coefficient compares the change in employment among the 55 to 57 age group that was affected by the payroll tax cut relative to the change in employment among the 52 to 54 age group that was not affected by the tax cut. Panel B calculates the percent change in employment using the difference-in-differences estimates from Panel A. The first row shows the employment rate in the treatment and control age groups in 2012, the year before the introduction of the payroll tax cut. The second row adds to that baseline the estimated change from Panel A. The third row shows the percent change in employment relative to the baseline. Panel C calculates the percent change in labor cost using an analogous difference-in-differences estimation for tax rates. Firms' labor cost is net wage times $(1+\tau_{ss})$, where τ_{ss} is the employer social security contribution. The reform cut τ_{ss} for workers in the treatment group. The first row shows the average labor cost in the control group between 2013-2015. The second row calculates the average labor cost for the treatment group taking into account the tax cut. The third row calculates the percent change in the labor cost caused by the tax cut. Panel D calculates the implied employment elasticity with respect to the wage change by taking the ratio of the percent change in employment (Panel B) and labor cost (Panel C). Standard errors are reported in brackets, clustered at the age $\times$ period level. ($N = 9,003,984$ individual-months)

Appendix Table B4: Employment Effects of the Tax Cut: Excluding Elementary Occupations From Employment Definition

	(1) All firms	(2) Low TFP	(3) High TFP
Panel A: Baseline employment definition			
Employment effect	0.0053***	0.0053***	-0.0001
	[0.0005]	[0.0005]	[0.0004]
Implied elasticity	-0.30	-0.53	0.01
	[0.03]	[0.05]	[0.06]
Panel B: Employment excluding elementary occupations			
Employment effect	0.0063***	0.0063***	-0.0000
	[0.0006]	[0.0005]	[0.0005]
Implied elasticity	-0.41	-0.73	0.00
	[0.04]	[0.06]	[0.07]

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: Table shows difference-in-differences estimates of the impact of the payroll tax cut on employment. Panel A shows the baseline results. In Panel B only employment in non-elementary occupations is considered. This is motivated by the fact that workers in elementary occupations were eligible for the tax cut independently of their age. We estimate the impact of the reform using regression (9). In particular, we report the β coefficient and estimate the regression with the outcome variable being employed at a private sector firm (column 1), at a private sector firm with below-median TFP (column 2), and at a private sector firm with above-median TFP (column 3). The β coefficient estimates the change in employment among the 55 to 57 age group that was affected by the payroll tax cut relative to the change in employment among the 52 to 54 age group that was not affected by the tax cut. Standard errors are reported in brackets, clustered at the age $\times$ period level. ($N = 9,003,984$ individual-months in both panels)

Appendix Table B5: Employment Effects of the Tax Cut: Alternative Sample Definitions

	(1) All firms	(2) Low TFP	(3) High TFP
Panel A: Baseline sample			
Employment effect	0.0053***	0.0053***	-0.0001
	[0.0005]	[0.0005]	[0.0004]
Implied elasticity	-0.30	-0.53	0.01
	[0.03]	[0.05]	[0.06]
Panel B: Sample with retirees			
Employment effect	0.0065***	0.0062***	-0.0001
	[0.0005]	[0.0004]	[0.0004]
Implied elasticity	-0.37	-0.64	0.01
	[0.03]	[0.05]	[0.06]

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: Table shows difference-in-differences estimates of the impact of the payroll tax cut on employment under different sample definitions. Panel A replicates the baseline results reported in Panel A of Table 2. Panel B shows the same estimates with retirees included in the sample. In both panels we estimate the impact of the reform using regression (9). In particular, we report the β coefficient and estimate the regression with the outcome variable being employed at a private sector firm (column 1), at a private sector firm with below-median TFP (column 2), and at a private sector firm with above-median TFP (column 3). The β coefficient estimates the change in employment among the 55 to 57 age group that was affected by the payroll tax cut relative to the change in employment among the 52 to 54 age group that was not affected by the tax cut. Standard errors are reported in brackets, clustered at the age $\times$ period level. ($N = 9,003,984$ individual-months in Panel A, $N = 9,482,667$ individual-months in Panel B)

Appendix Table B6: Employment Effects of the Tax Cut: Short-run Estimates

	(1) Employment, baseline	(2) Employment, TFP	(3) Employment, foreign ownership	(4) Employment, firm-level wage	(5) Employment, AKM FE
All firms	0.0029***				
	[0.0005]				
Low-quality firms		0.0045***	0.0035***	0.0032***	0.0036***
		[0.0004]	[0.0004]	[0.0003]	[0.0004]
High-quality firms		-0.0016***	-0.0006	-0.0003	-0.0007
		[0.0005]	[0.0003]	[0.0005]	[0.0006]

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: Table shows difference-in-differences estimates of the short-run impact of the payroll tax cut on private sector employment. Column (1) and (2) replicate the analysis in Panel A of Table 2, but restrict the sample to the period between 2012 (the year before the policy change) and 2013 (the year after the policy change) instead of focusing on the period between 2012 and 2015 as in Table 2). We estimate the impact of the reform using regression (9). In particular, we report the β coefficient and estimate the regression with the outcome variable being employed at a private sector firm (row 1), at a low-quality private sector firm (row 2) and at a high-quality private sector firm (row 3). Columns (3)-(5) report robustness to using different quality measures. Column (3) reports estimates by ownership. In Hungary foreign-owned firms offer the highest-paying, highest-quality jobs. In column (4) we measure firm quality by the average wage the firms pays. Finally, in column (5) we measure firm quality based on the firm-level wage premium estimated using an Abowd, Kramarz, Margolis (AKM) style decomposition. Standard errors are reported in brackets, clustered at the age $\times$ period level. ($N = 4,711,215$ individual-months)

Appendix Table B7: Employment and Wage Effects of the Tax Cut: Robustness to Using Measures of Firm-Quality Based on Pre-Reform Years

	(1)	(2)	(3)	(4)
Panel A: Employment				
Firm quality uses all years	TFP	Foreign ownership	Firm-level wage	AKM FE
Low-quality firms	0.0053***	0.0060***	0.0048***	0.0047***
	[0.0005]	[0.0004]	[0.0003]	[0.0004]
High-quality firms	-0.0001	-0.0007**	0.0005	0.0005
	[0.0004]	[0.0003]	[0.0004]	[0.0004]
Firm quality uses pre-reform years only	TFP	Foreign ownership	Firm-level wage	AKM FE
Low-quality firms	0.0059***	0.0062***	0.0040***	0.0032***
	[0.0005]	[0.0004]	[0.0003]	[0.0004]
High-quality firms	-0.0006	-0.0008**	0.0013***	0.0010**
	[0.0005]	[0.0003]	[0.0004]	[0.0004]
Panel B: Log(wage), pass-through rate				
Firm quality uses all years	TFP	Foreign ownership	Firm-level wage	AKM FE
Low-quality firms	-0.077	-0.042	0.030	-0.115
	[0.070]	[0.101]	[0.139]	[0.167]
High-quality firms	0.602***	1.137***	0.993***	1.119***
	[0.131]	[0.211]	[0.167]	[0.233]
Firm quality uses pre-reform years only	TFP	Foreign ownership	Firm-level wage	AKM FE
Low-quality firms	-0.094	-0.105	0.219*	-0.113
	[0.119]	[0.139]	[0.113]	[0.078]
High-quality firms	0.547***	1.236***	1.103***	1.019***
	[0.108]	[0.180]	[0.200]	[0.224]

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: Table shows difference-in-differences estimates of the impact of the payroll tax cut on employment, assessing robustness to defining firm quality using only pre-reform years (instead of all years). Panel A shows the effect of tax cut on employment and Panel B on wages. The first part of each panel replicates the baseline results in Tables 2 and 7 for employment and wages, respectively. In the baseline specification firm quality indicators are generated using years between 2010 and 2015, except for the AKM firm effects, which use years between 2003 and 2012. The second part of each panel assesses the impact of the tax cut using quality measures relying only on pre-reform years. In this panel TFP, firm-level wage and foreign ownership are defined based on year 2012. The AKM firm fixed effect is estimated using all pre-policy years (2003 and 2012). In Panel A we report the β coefficient from regression equation (9). In Panel B we report the pass-through rate. The pass-through rate at low-productivity firms is the β_1 coefficient on the After $\times$ Treated $\times$ TCR term in equation (13), while at the high-productivity firms it is the sum of that coefficient and the β_3 coefficient on High-quality $\times$ After $\times$ Treated $\times$ TCR in equation (13). Standard errors are reported in brackets, clustered at the age $\times$ period level.

Appendix Table B8: Employment Effects of the Tax Cut: Heterogeneity by Firm Size

	(1)	(2)	(3)
		Employment	
	All firms	Low TFP	High TFP
Firms with 1-49 workers	0.0015***	0.0015***	0.0001
	[0.0004]	[0.0003]	[0.0002]
	{39%}	{33%}	{6%}
	⟨0.1272⟩	⟨0.1074⟩	⟨0.0198⟩
Firms with 50+ workers	0.0036***	0.0035***	0.0001
	[0.0005]	[0.0003]	[0.0005]
	{61%}	{18%}	{43%}
	⟨0.2021⟩	⟨0.0608⟩	⟨0.1413⟩

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: Table shows difference-in-differences estimates of the impact of the payroll tax cut on employment separately for micro and small-sized firms (1-49 workers) and medium and large firms (50+ workers). In the top row we report the β coefficient from regression equation (9) with the outcome variable being whether someone is employed at a micro/small sized firm, at a micro/small sized firm with below-median (column 2) or above-median (column 3) TFP. In the bottom row we report the β coefficient from regression equation (9) with the outcome variable being whether someone is employed at a medium/large sized firm, at a medium/large sized firm with below-median (column 2) or above-median (column 3) TFP. In curly brackets, we show the share of individuals working at different sized (and different productivity) firms, while in angle brackets we show the mean of the outcome variable in May 2012. Standard errors are reported in brackets, clustered at the age × period level. ($N = 9,003,984$ individual-months)

Appendix Table B9: Wage Effects of the Tax Cut: Heterogeneity by Firm Size

	(1) log(wage)	(2) log(wage)
After × Treated	-0.002	0.020
	[0.016]	[0.016]
After × Treated × TCR	0.028	-0.234
	[0.136]	[0.174]
High TFP × After × Treated	-0.027	-0.061***
	[0.034]	[0.017]
High TFP × After × Treated × TCR	0.422	0.889***
	[0.285]	[0.167]
Pass-through rate		
Low TFP	0.028	-0.234
	[0.136]	[0.174]
High TFP	0.450	0.653***
	[0.290]	[0.128]
Observations	35,862	61,861
Firm size	1-49 workers,	50+ workers
Quality measure	TFP	TFP
New entrants vs. incumbents	incumbents	incumbents
Workers	all	all
Part-time included	no	no
One vs. two year change	one	one

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: Table shows difference-in-differences estimates of the impact of the payroll tax cut on private sector wages based on estimating equation (13). In column (1), the sample is restricted to workers employed at micro and small-sized firms (1-49 workers). In column (2), the sample is restricted to workers employed at medium and large firms (50+ workers). The difference-in-differences estimate compares the change in wages among the 55 to 57 age group that was affected by the payroll tax cut with the change in wages among the 52 to 54 age group that was not affected by the tax cut. The pass-through rate at low-productivity firms is the β_1 coefficient on the After × Treated × TCR term in equation (13), while at high-productivity firms it is the sum of the β_1 coefficient and the β_3 coefficient on the High TFP × After × Treated × TCR term in equation (13). Standard errors are reported in brackets, clustered at the age × period level.

Appendix Table B10: Employment Effects of the Tax Cut: Heterogeneity by Local Labor Market Conditions

	(1)	(2)
	Employment	
	Low TFP	High TFP
Panel A: By unemployment rate		
Districts with below-median unemployment rate in 2012	0.0055***	-0.0014**
	[0.0008]	[0.0007]
	⟨0.1807⟩	⟨ 0.2040⟩
Observations	3,603,336	3,603,336
Districts with above-median unemployment rate in 2012	0.0065***	-0.0003
	[0.0008]	[0.0008]
	⟨0.1706⟩	⟨0.1315⟩
Observations	3,938,028	3,938,028
Panel B: By change in labor market conditions		
Districts with stable labor market conditions	0.0050***	-0.0005
	[0.0005]	[0.0005]
	⟨0.1650⟩	⟨0.1585⟩
Observations	5,278,340	5,278,340
Districts with improving labor market conditions	0.0051***	0.0011
	[0.0007]	[0.0008]
	⟨0.1718⟩	⟨ 0.1601⟩
Observations	4,400,856	3,421,239
Panel C: By share of older workers		
Districts with below-median ratio of aged 55-57	0.0054***	-0.0007
	[0.0006]	[0.0006]
	⟨0.1538⟩	⟨0.1662⟩
Observations	4,287,445	4,287,445
Districts with above-median ratio of aged 55-57	0.0050***	0.0009*
	[0.0007]	[0.0004]
	⟨0.1808⟩	⟨0.1583⟩
Observations	4,716,539	4,716,539

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: Table explores the heterogeneity in the employment effects of the tax cut by local labor market characteristics. In Panel A, the employment changes are studied separately for districts with below- and above-median unemployment rates in 2012. The mean unemployment rate was 8.6% in districts with below-median unemployment rate and 18.3% in districts with above-median unemployment rate. In Panel B, we study the employment effects of the tax cut separately in stable and in improving labor markets. In districts with stable labor market conditions, the change in private sector employment rate between 2012 and 2015 was between -2 and +2 percentage points, with a mean of 0.1 percentage point. In districts with improving labor market conditions, the change in private sector employment rate between 2012 and 2015 was above +2 percentage points, with a mean of 3 percentage points. We exclude here the few deteriorating labor markets with more than -2 percentage points decline in private sector employment rate. In Panel C, we show employment effects separately for districts with below- and above-median shares of men aged 55 and 57 within the male population in 2012. The mean share was 0.074 in districts with a below-median share and 0.085 in districts with an above-median share. In each panel, and for each region, we apply the same difference-in-differences estimate as in Panel A of Table 2. In particular, we report the β coefficient from regression equation (9) with the outcome variable being employed at a private sector firm with below-median productivity (column 1) and at a private sector firm with above-median productivity (column 2). In angle brackets, we show the mean of the outcome variable in May 2012. Standard errors are reported in brackets, clustered at the age × period level.

Appendix Table B11: Wage Effects of the Tax Cut, Using Lagged Firm Productivity Measures

	(1) log(wage)	(2) log(wage)	(3) log(wage)	(4) log(wage)
After × Treated	0.008	0.022***	-0.026***	0.011
	[0.005]	[0.007]	[0.006]	[0.013]
After × Treated × TCR	-0.062	-0.174**	0.210***	-0.097
	[0.053]	[0.068]	[0.046]	[0.181]
High TFP × After × Treated	-0.044***	-0.036***	-0.038***	-0.051**
	[0.023]	[0.008]	[0.017]	[0.018]
High TFP × After × Treated × TCR	0.587***	0.484***	0.540***	0.687***
	[0.122]	[0.064]	[0.076]	[0.201]
Windfall rate × After × Treated				0.561*
				[0.309]
Windfall rate × After × Treated × TCR				-6.324**
				[2.601]
Pass-through rate				
Low TFP	-0.062	-0.174**	0.210***	-0.097
	[0.053]	[0.068]	[0.046]	[0.181]
High TFP	0.525***	0.310***	0.750***	0.590***
	[0.124]	[0.095]	[0.067]	[0.092]
Observations	97,789	112,713	82,910	97,789
New entrants vs. incumbents	incumbents	incumbents	incumbents	incumbents
Workers	all	all	all	all
Part-time included	no	yes	no	no
One vs. two year change	one	one	two	one
Windfall rate included	no	no	no	yes

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: Table shows difference-in-differences estimates of the impact of the payroll tax cut on wages when we use lagged firm productivity ($Q_{j(it-1)}$) in the regression equation (13) instead of current firm productivity $Q_{j(it)}$. Columns (1)-(4) estimate heterogeneity by firm productivity using equation (13) (but with lagged firm productivity measure). In all columns except column (2) we focus on full-time workers. In column (2) we also include part-time workers in the analysis. In all columns except in column (3), we compare the wage changes between 2012 and 2013. In column (3) we study two-year wage changes and compare the wage change between 2012 and 2014. In column (4), we also interact the treatment, age, year, and tax cut rate indicators with the firm specific windfall rate, which reflects the size of the windfall received by the firm as a result of the tax cut. Following (Saez, Schoefer and Seim, 2019) we calculate this as the (lagged) ratio of age- and occupation specific payroll tax cuts payable after the reform and the total payroll. The difference-in-differences estimate compares the change in wages among the 55 to 57 age group that was affected by the payroll tax cut with the change in employment among the 52 to 54 age group that was not affected by the tax cut. The pass-through rate at low-productivity firms is the β_1 coefficient on the After × Treated × TCR term in equation (13), while at high-productivity firms it is the sum of the β_1 coefficient and the β_3 coefficient on the High TFP × After × Treated × TCR term in equation (13). Standard errors are reported in brackets, clustered at the age × period level.

Appendix Table B12: Wage Effects of the Tax Cut by Various Firm Quality Indicators, Wage Model Extended with Windfall Indicator

	(1) log(wage)	(2) log(wage)	(3) log(wage)	(4) log(wage)	(5) log(wage)	(6) log(wage)	(7) log(wage)	(8) log(wage)
After × Treated	0.008	0.011	0.003	0.006	-0.0004	0.011	0.010	0.025
	[0.007]	[0.016]	[0.011]	[0.008]	[0.016]	[0.019]	[0.020]	[0.024]
After × Treated × TCR	-0.077	-0.129	-0.042	-0.101	0.030	-0.094	-0.115	-0.272
	[0.070]	[0.215]	[0.101]	[0.129]	[0.139]	[0.189]	[0.167]	[0.237]
High-quality × After × Treated	-0.046***	-0.053**	-0.068***	-0.070***	-0.054***	-0.065***	-0.072***	-0.082***
	[0.032]	[0.021]	[0.014]	[0.013]	[0.008]	[0.012]	[0.014]	[0.021]
High-quality × After × Treated × TCR	0.678***	0.780***	1.179***	1.222***	0.963***	1.073***	1.235***	1.345***
	[0.137]	[0.242]	[0.211]	[0.235]	[0.051]	[0.109]	[0.160]	[0.255]
Windfall rate × After × Treated		0.546*		0.391		-0.111		-0.150
		[0.277]		[0.286]		[0.257]		[0.268]
Windfall rate × After × Treated × TCR		-5.979**		-4.141**		-0.412		0.588
		[2.588]		[1.716]		[1.208]		[2.247]
Pass-through rate								
Low-quality	-0.077	-0.129	-0.042	-0.101	0.030	-0.094	-0.115	-0.272
	[0.070]	[0.215]	[0.101]	[0.129]	[0.139]	[0.189]	[0.167]	[0.237]
High-quality	0.602***	0.651***	1.137***	1.121***	0.993***	0.979***	1.119***	1.074***
	[0.131]	[0.097]	[0.211]	[0.176]	[0.167]	[0.164]	[0.233]	[0.199]
Observations	97,789	97,789	97,789	97,789	97,789	97,789	97,789	97,789
Quality measure	TFP	TFP	foreign-owned	foreign-owned	firm-level wage	firm-level wage	AKM FE	AKM FE
New entrants vs. incumbents	incumbents	incumbents	incumbents	incumbents	incumbents	incumbents	incumbents	incumbents
Workers	all	all	all	all	all	all	all	all
Part-time included	no	no	no	no	no	no	no	no
One vs. two year change	one	one	one	one	one	one	one	one
Windall rate included	no	yes	no	yes	no	yes	no	yes

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: Table shows the wage effects of the tax cut by various firm quality indicators. The odd columns in the table repeat the estimates of Table 7 showing the difference-in-differences estimates of the impact of the payroll tax cut on private sector wages based on estimating equation (13). In all even columns, we also interact the treatment, age, year, and tax cut rate indicators with the firm-specific windfall rate, which reflects the size of the windfall received by the firm as a result of the tax cut. Following (Saez, Schoefer and Seim, 2019) we calculate this as the (lagged) ratio of age- and occupation specific payroll tax cuts payable after the reform and the total payroll. In columns (1) and (2) we use TFP as the firm quality indicator. In columns (3) and (4) we measure quality based on ownership. In Hungary foreign-owned firms are the most productive firms offering the highest-paying, highest-quality jobs. In columns (5) and (6) we measure firm quality by the average wage the firms pays. Finally, in columns (7) and (8) we measure firm quality based on the firm-level wage premium estimated using an Abowd, Kramarz, Margolis (AKM) style decomposition. The difference-in-differences estimate compares the change in wages among the 55 to 57 age group that was affected by the payroll tax cut with the change in employment among the 52 to 54 age group that was not affected by the tax cut. Standard errors are reported in brackets, clustered at the age × period level.

Appendix Table B13: Wage Effects of the Tax Cut: Heterogeneity by Education

	(1) Primary and lower-secondary jobs, log(wage)	(2) Upper-secondary and tertiary jobs, log(wage)	(3) Primary and lower-secondary jobs, log(wage)	(4) Upper-secondary and tertiary jobs, log(wage)
After × Treated	0.032***	-0.014	0.005	-0.001
	[0.010]	[0.011]	[0.078]	[0.208]
After × Treated × TCR	-0.285***	0.209	-0.060	0.038
	[0.084]	[0.135]	[0.009]	[0.026]
High-quality × After × Treated	-0.053***	-0.037	-0.042*	-0.081***
	[0.013]	[0.021]	[0.021]	[0.022]
High-quality × After × Treated × TCR	0.643***	0.792**	0.731**	1.990***
	[0.130]	[0.308]	[0.276]	[0.458]
Pass-through rate				
Low-quality	-0.285***	0.209	-0.060	0.038
	[0.084]	[0.135]	[0.078]	[0.208]
High-quality	0.358*	1.001***	0.671**	2.028***
	[0.164]	[0.193]	[0.292]	[0.525]
Observations	66,180	30,794	66,180	30,794
Quality measure	TFP	TFP	AKM FE	AKM FE
New entrants vs. incumbents	incumbents	incumbents	incumbents	incumbents
Workers	all	all	all	all
Part-time included	no	no	no	no
One vs. two year change	one	one	one	one
Windall rate included	no	no	no	no

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: Table shows difference-in-differences estimates of the impact of the payroll tax cut on private sector wages based on estimating equation (13). The sample is split by education categories of jobs (measured at the previous year), which are defined by imputing the modal education level of employees of the same four-digit occupation code in the 2013 Labor Force Survey of the Central Statistical Office of Hungary. The difference-in-differences estimate compares the change in wages among the 55 to 57 age group that was affected by the payroll tax cut with the change in employment among the 52 to 54 age group that was not affected by the tax cut. The pass-through rate at low-productivity firms is the β_1 coefficient on the After × Treated × TCR term in equation (13), while at high-productivity firms it is the sum of the β_1 coefficient and the β_3 coefficient on the High TFP/AKM FE × After × Treated × TCR term in equation (13). In columns (1) and (2), we use TFP as firm quality indicator, in columns (3) and (4) we use the firm-level wage premium estimated using an Abowd, Kramarz, Margolis (AKM) style decomposition. Standard errors are reported in brackets, clustered at the age × period level.

C Effect on Women

Women were eligible for the payroll tax cut but they were also targeted by a pension policy introduced in 2011. The so-called "Women 40" policy grants an early retirement option for women with 40 years of work credits, regardless of age. Years spent on maternity benefits also count towards the work credits, with the restriction that a woman must have been employed for 32 years (or at least 25 years if she has 5 or more children). Unfortunately, our data do not allow us to determine eligibility as we do not observe the full employment history of older people in our sample.

Even though this reform is unlikely to have a major effect on the employment of the treated population (age 55-57), we exclude women from the main analysis to ensure that our results are not driven by the pension policy. In this section, we estimate the employment and wage effects of the payroll tax cut among older women. The main conclusions are summarized in Section 7.1, while we provide more detail below.

Employment effects. We estimate the same difference-in-differences model for women as for men, specified in equation (9). The control and treatment groups consist of women aged 52-54 and 55-57, respectively. We compare the change in their employment between 2012 and the 2013-2015 period, the year before and the years after the introduction of the payroll tax cut. Among older women private sector employment increased by 0.51 percentage points (2.16%) as a result of the tax cut (see Table C1).The overall employment effect was almost identical among men (0.53 percentage points, 1.59%). Table C1 also shows the implied labor demand elasticity. The 5.35% decrease in labor costs and the resulting 2.16% increase in employment of women aged 55-57 over 2013-2015 imply a labor demand elasticity of -0.40. Overall, the employment effect and the implied labor demand elasticity are similar among older women and men, though somewhat larger among women.

Heterogeneity by firm productivity. To investigate whether the employment effect for women differs by firm productivity, we estimate the difference-in-differences model, specified in equation (9) with the outcome variable being employment either at a low-TFP or at a high-TFP firm. We apply exactly the same definition for low- and high-TFP firms as for men: low (high) TFP firms are defined as firms below (above) the worker weighted median total factor productivity calculated based on all prime age adults (including men and women). Table C2 shows that private sector employment of older women increases more at low-productivity firms, the increase is 0.37 vs. 0.14 percentage points at low- vs. high-TFP firms. This translates into a -0.48 (s.e. 0.07) employment elasticity at low-TFP firms and a -0.29 (s.e. 0.10) employment elasticity at high-TFP ones. Therefore there is a clear and statistically significant difference in the employment responses at high- and low-productivity firms albeit those differences are less stark for women than for men.

To see whether the heterogeneous employment effects are driven by firm or employee characteristics we estimate heterogeneity by firm productivity among similar workers. Looking at low-paid occupations, Table C2 shows that employment of women at low-productivity firms increased by 0.21 percentage points while the change in employment at high-productivity firms is close to zero (the same estimates are 0.30 and -0.01 for men). Similarly, looking

at jobs where the modal education level is primary or lower-secondary school according to the Labor Force Survey (LFS), the employment effect is 0.22 percentage points at low-productivity firms compared to only 0.08 percentage points at high-productivity firms (0.37 vs. -0.01 for men). Overall, the findings highlight that the impact of the tax cut among women is smaller at high-productivity firms than at low-productivity firms, especially at low-paid jobs and lower education level of the employee. This suggests that the heterogeneous employment patterns are driven by firm heterogeneity and not worker heterogeneity.

Wage effects by firm productivity. We also estimate the wage effects of the tax cut among older women. Figure C1 shows the wage effects from 2012 to 2013 for women by firm productivity at different levels of the effective tax cut. The patterns of wage effects are similar for women and men (see Figure 10 for men). Wages increase only at high-TFP firms and only at lower wage levels with a higher corresponding effective tax cut rate. However, the wage increase we see at high-productivity firms is somewhat smaller for women than for men.

Appendix Table C1: Elasticity of Employment: Women

	(1) All firms	(2) Low TFP	(3) High TFP
Panel A: Change in the probability of employment			
— $After \times Treated$	0.0051^{***}	0.0037^{***}	0.0014^{***}
	[0.0007]	[0.0005]	[0.0005]
Panel B: Percent change in employment			
—Employment without tax cut	0.236	0.130	0.106
—Employment with tax cut	0.241	0.134	0.107
—Percent change in employment	2.16%	2.85%	1.32%
Panel C: Percent change in labor cost $(1+\tau_{ss})$			
—Labor cost without tax cut	1.26	1.25	1.27
—Labor cost with tax cut	1.19	1.17	1.21
—Percent change in labor cost	-5.35%	-5.88%	-4.60%
Panel D: Implied elasticity (Panel B/Panel C)			
— Elasticity	-0.40	-0.48	-0.29
	[0.06]	[0.07]	[0.10]

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: Table applies the same analysis for women as Table 2 for men. Panel A of the table shows difference-in-differences estimates of the impact of the payroll tax cut on private sector employment for all firms (column 1) and separately for below-median (column 2) and above-median (column 3) TFP firms in Panel A. We report the β coefficient from regression equation (9) with the outcome variable being employed at a private sector firm (column 1), at a private sector firm with below-median productivity (column 2) and at a private sector firm with above-median productivity (column 3). The β coefficient estimates the change in employment among the 55 to 57 age group that was affected by the payroll tax cut relative to the change in employment among the 52 to 54 age group that was not affected by the tax cut. Panel B calculates the percent change in employment using the difference-in-differences estimates from Panel A. The first row shows the employment rate in the treatment and control age groups in 2012, the year before the introduction of the payroll tax cut. The second row adds to that baseline the estimated change from Panel A. The third row shows the percent change in employment relative to the baseline. Panel C calculates the percent change in labor cost using an analogous difference-in-differences estimation for tax rates. Firms' labor cost is net wage times $(1+\tau_{ss})$, where τ_{ss} is the employer social security contribution. The reform cut τ_{ss} for workers in the treatment group. The first row shows the average labor cost in the control group between 2013-2015. The second row calculates the average labor cost for the treatment group taking into account the tax cut. The third row calculates the percent change in the labor cost caused by the tax cut. Panel D calculates the implied employment elasticity with respect to the wage change by taking the ratio of the percent change in employment (Panel B) and labor cost (Panel C). Standard errors are reported in brackets, clustered at the age $\times$ period level. ($N = 9,529,124$ individual-months)

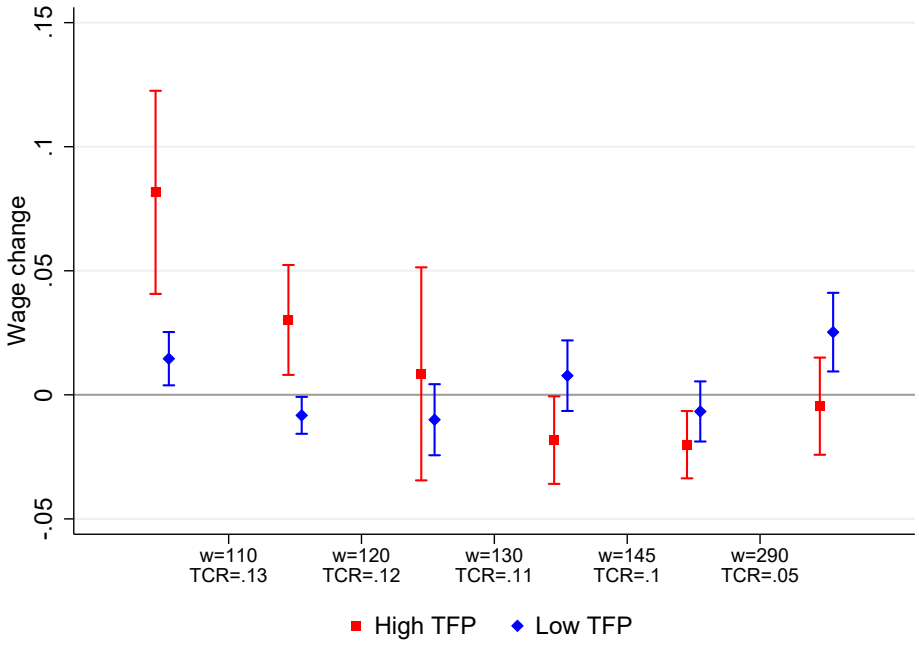
Appendix Table C2: Employment Effects of the Tax Cut by Subgroups for Men and Women

	(1)	(2)	(3)	(4)	(5)	(6)
	Employment, men			Employment, women		
	All firms	Low TFP	High TFP	All firms	Low TFP	High TFP
All jobs	0.0053***	0.0053***	-0.0001	0.0051***	0.0037***	0.0014***
	[0.0005]	[0.0005]	[0.0004]	[0.0007]	[0.0005]	[0.0005]
Panel A: By wage						
Jobs paying at most 1.5×minimum wage	0.0039***	0.0032***	0.0007***	0.0062***	0.0046***	0.0016***
	[0.0005]	[0.0004]	[0.0002]	[0.0005]	[0.0004]	[0.0003]
	{35%}	{27%}	{8%}	{33%}	{20%}	{12%}
Jobs paying above 1.5×minimum wage	0.0016***	0.0019***	-0.0003	-0.0011**	-0.0007**	-0.0004
	[0.0005]	[0.0003]	[0.0005]	[0.0005]	[0.0003]	[0.0004]
	{65%}	{24%}	{40%}	{67%}	{36%}	{31%}
Panel B: By occupation						
Low-paid occupation	0.0028***	0.0030***	-0.0001	0.0021***	0.0021***	-0.0000
	[0.0004]	[0.0003]	[0.0002]	[0.0005]	[0.0003]	[0.0004]
	{51%}	{28%}	{24%}	{57%}	{36%}	{20%}
High-paid occupations	0.0024***	0.0023***	0.0001	0.0030***	0.0015***	0.0014***
	[0.0006]	[0.0003]	[0.0005]	[0.0005]	[0.0004]	[0.0004]
	{49%}	{19%}	{30%}	{43%}	{21%}	{22%}
Panel C: By education						
Primary and lower-secondary education jobs	0.0038***	0.0037***	-0.0001	0.0029***	0.0022***	0.0008**
	[0.0005]	[0.0004]	[0.0003]	[0.0005]	[0.0003]	[0.0003]
	{70%}	{37%}	{33%}	{52%}	{31%}	{21%}
Upper-secondary education jobs	-0.0000	0.0004**	-0.0004	0.0011***	0.0007**	0.0004*
	[0.0003]	[0.0002]	[0.0003]	[0.0003]	[0.0003]	[0.0003]
	{16%}	{8%}	{8%}	{38%}	{19%}	{16%}
Tertiary education jobs	0.0013***	0.0011***	0.0001	0.0013***	0.0010***	0.0003
	[0.0003]	[0.0002]	[0.0003]	[0.0002]	[0.0001]	[0.0002]
	{14%}	{7%}	{7%}	{12%}	{6%}	{6%}

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: Table applies the same analysis for both men and women as Table 4 for men. The table shows difference-in-differences estimates of the impact of the payroll tax cut on private sector employment based on estimating equation (9) separately for various subgroups. Panel A considers employment in jobs paying above vs. below 150% of the minimum wage. Panel B considers employment in occupations with above- vs. below-median average wages in 2012. Panel C considers employment in occupations requiring different levels of education, defined as the modal level of education in the Labor Force Survey in 2012. In each case we estimate the regression equation (9) using employment in a given subgroup (job or occupation) and firm type (all firms in columns 1 and 4, below-median TFP firms in columns 2 and 5, and above-median TFP firms in columns 3 6) as the outcome variable. In curly brackets we report the subgroup share within each panel. In angle brackets we report the mean of the outcome variable in May 2012—the probability of being employed in a given subgroup and firm type. The difference-in-differences estimate compares the change in employment among the 55 to 57 age group that was affected by the payroll tax cut with the change in employment among the 52 to 54 age group that was not affected by the tax cut. Standard errors are reported in brackets, clustered at the age × period level. ($N = 9,003,984$ individual-months for men, $N = 9,529,124$ individual-months for women)

Appendix Figure C1: Wage Changes at Different Levels of Lagged Wages: Women



Note: Figure applies the same analysis for women as Figure 10 for men. In particular, figure shows difference-in-differences estimates of the payroll tax cut on private sector wages separately for low- and high-productivity (TFP) firms by lagged wage. The payroll tax cut was 14,500 HUF and so the tax cut rate, $TCR_{it-1} = 14,500/w_{it-1}$, falls as lagged wages increase. Estimates are based on a modified version of equation (13), where the linear tax cut rate TCR_{it-1} in the last interaction term is replaced with categories of the tax cut rate TCR_{it-1}. We report the cut-off values of lagged wages (in thousands of Hungarian forints) and the corresponding tax cut rates TCR_{it-1} on the x-axis of the figure. The estimates display the change in log wages among the 55 to 57 age group that was affected by the payroll tax cut relative to the change in log wages among the 52 to 54 age group that was not affected by the tax cut for above-median (in red) and below-median (in blue) TFP firms. 95% confidence intervals are reported with standard errors clustered at the age $\times$ period level.

D Effect on Younger Workers

Parallel to the introduction of the payroll tax cut for older workers, a similar tax cut was applied for under-25 workers. We briefly summarize the main results we find for younger workers in Section 7.2 and we provide further details below.

We estimate the impact of the payroll tax cut in a difference-in-differences framework, comparing younger workers below the age 25 cutoff to workers just above (ages 22-24 vs. 25-27) during 2012-2015 (before and after the introduction of the tax cut in 2013). In 2015, the government introduced the Youth Guarantee Program recommended by the European Council, which targeted workers younger than age 25, however the take-up rate of the program was very small. In 2015 there were only a few thousand participants. The exclusion of the participants in the Youth Guarantee Program does not affect our results.

Employment effects. We replicate the main analyses from Section 4 for younger workers. First, Figure D1 shows the effective average payroll tax rate for ages 20-40 before and after the implementation of the tax cut. We see a discontinuity at age 25 after the policy was implemented (in gray) compared to the constant rate of 28.5% before (in black). There is a jump from 17% to 24% from age 24 to 25, which is a slightly larger average effective tax cut than for workers above 55 (a cut of 7 vs. 6 percentage points for the younger and older age groups, respectively). At younger ages the effective tax cut decreases with age, which reflects the gradual increase in wages and thus the lower proportional tax cut. Furthermore, career starters received some extra tax cuts and the share of those workers steadily declines with age.

Figure D2 depicts employment in private sector companies for men by age before and after the payroll tax cut was introduced in 2013. Panel (a) shows raw employment rates by age before (year 2012, in black) and after the policy (years 2013-2015, in gray). It shows that employment rates increase rapidly with age between ages 20 and 26, are roughly constant between ages 26 and 35 and then start declining slowly. Comparing the period before and after the policy, this figure suggests that employment rates were similar in 2012 and 2013-2015 for most age groups, but show a clear divergence below 26.

Panel (b) shows estimates of the age-specific differences in employment at private sector companies for men before vs. after the payroll tax cut was introduced. It suggests that for ages above 25 changes in employment rates were close to zero (somewhat below zero at age 35 and at ages 39-40) but age-specific employment levels strongly diverge between the pre- and the post-reform periods among younger workers below 25. A 24-year-old worker was close to 2 percentage points more likely to be employed shortly after the policy was introduced (years 2013-2015). The gap widens as age decreases, which likely reflects the fact that in employment relationships formed at younger ages there is more time left until the tax cut phases out at age 25. Overall, this figure suggests that the payroll tax cut had a positive employment effect among younger workers. This effect is larger than for older employees above 55 (2 vs. 1 percentage point).

We estimate the same difference-in-differences regression for younger workers as for older workers (specified in equation (9)), where employees aged 22-24 are in the treatment group and the 25-27 age group acts as control group. Table D1 shows the baseline results for younger workers. Among younger workers private sector employment increased by 1.6 per-

centage points (5.1%) as a result of the payroll tax cut, compared to the 0.53 percentage points (1.6%) increase among older workers. We also show the elasticity of employment in Table D1. The 1.6 percentage points (5.1%) increase in employment and the 6.6% decrease in labor costs for the 22-24 age group over years 2013-2015 imply a labor demand elasticity of -0.77. Overall, the employment effect is larger and labor demand is more elastic for younger workers.

Employment effects by firm quality. We also assess whether the treatment effect differs by firm productivity among younger workers. Table D1 reports separate estimates for low- and high-productivity firms. In line with the results for older workers, we find a significantly smaller employment elasticity (-0.67, s.e. 0.06) for workers at high-productivity firms than for workers at low-productivity firms (-0.92, s.e. 0.06). In Figure D3 (which is analogous to Panel (a) of Figure 7 for the older age group), we also report the employment effects by other firm quality indicators. The estimates show even larger heterogeneity in responses when we measure firm quality by ownership (foreign vs. domestic), average wage, or AKM firm effects.

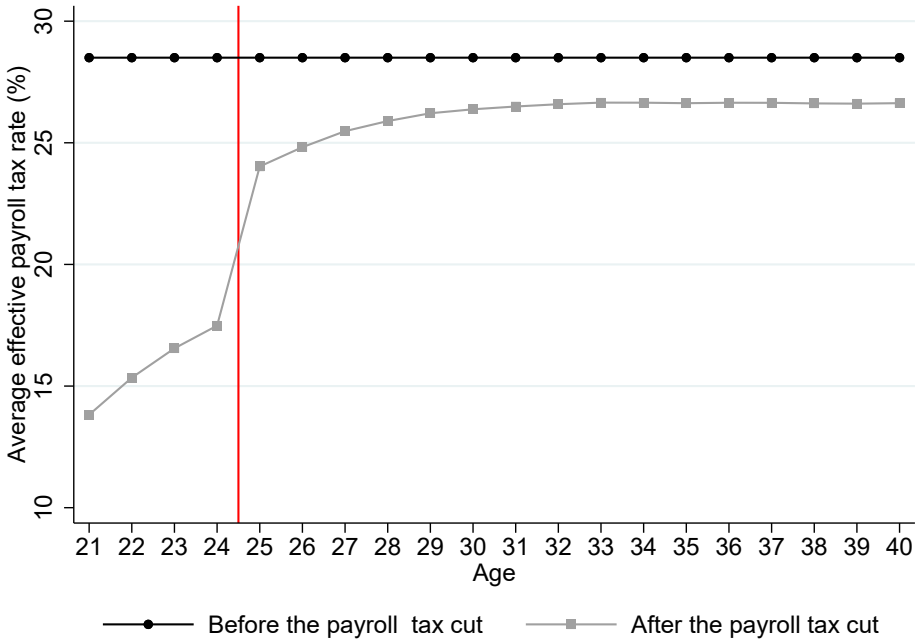
Furthermore, our theoretical framework predicts that the employment effects should be less heterogeneous whenever the share of new entrants is larger. In line with that prediction of the model we show in Table D2 that there is large heterogeneity in employment responses among experienced younger workers (those who enter the labor market around age 18), while we find limited heterogeneity among non-experienced younger workers who are entering the labor market at later ages.

Wage effects. We assess the impact on wages among younger workers in a similar fashion as for older workers, using a modified version of equation (13) (replacing the linear tax cut rate in the last interaction term with categories of the tax cut rate). Figure D4 shows the wage effects for younger workers from 2012 to 2013 at different levels of the effective tax cut rate. We find no significant change in wages at any level of the tax cut rate. Also, there is no heterogeneity by firm productivity, which might be due to the fact that a higher share of younger workers are new entrants, who have limited employment histories, or have fixed term contracts that cannot used as an outside option in wage negotiations. For these workers our theoretical model predicts little wage effects of the tax cut.

Windfall effects. We also assess potential windfall effects at firms that already employed many younger workers from the treatment age group (below age 25) before the tax cut was implemented, following the strategy of Saez, Schoefer and Seim (2019). We compare firms that have a high share of treated workers below age 25 with firms that have a medium share in 2012 (last pre-reform year), the same exercise as for older workers in Appendix Figure B4. Again, Panel (a) of Figure D5 indicates mean reversion in the exposure to the tax cut (ratio of the windfall revenues to the total payroll) and net wages trend similarly for firms with high and medium shares of younger treated workers (Panel (c)). However, we see some divergence in the evolution of firm size and sales revenue (Panel (b) and (d) of Figure D5); both of them grew faster at firms with high exposure, suggesting a small positive impact of a larger tax windfall on growth. These figures are similar to the findings of Saez, Schoefer

and Seim (2019) on the young workers' tax cut in Sweden, suggesting that responses to a tax cut have many similar features in the two countries and economic environments. At the same time, the figures differ from what we found for older workers. This suggests that the windfall effects documented by Saez, Schoefer and Seim (2019) might be less relevant for firms employing older workers.

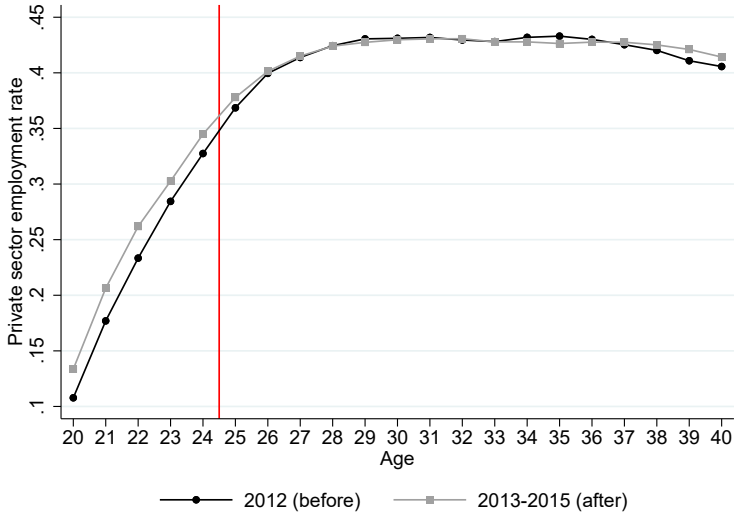
Appendix Figure D1: Employers' Social Security Contribution Rate by Workers' Age: Younger Workers



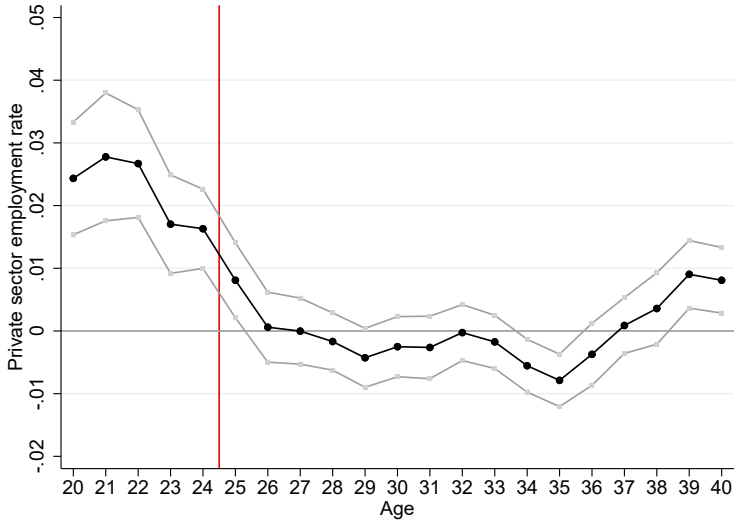
Note: Figure applies the same analysis for younger workers as Figure 2 for older workers. In particular, figure shows the average employer social security contribution rate by worker age for male workers in the private sector. Before the implementation of the payroll tax cut, the payroll tax rate was a flat 28.5%. Between 2013-2015 (after the implementation of the cut) all individuals over up to age 24 experienced a lump-sum tax cut of HUF 14,500 per month (around 6% of the average salary). Certain individuals were also eligible for the tax cut independently of their age (see Section 3.1 for the details).

Appendix Figure D2: Employment in Private Sector Companies by Age: Younger Workers

(a) Private Sector Employment Rate

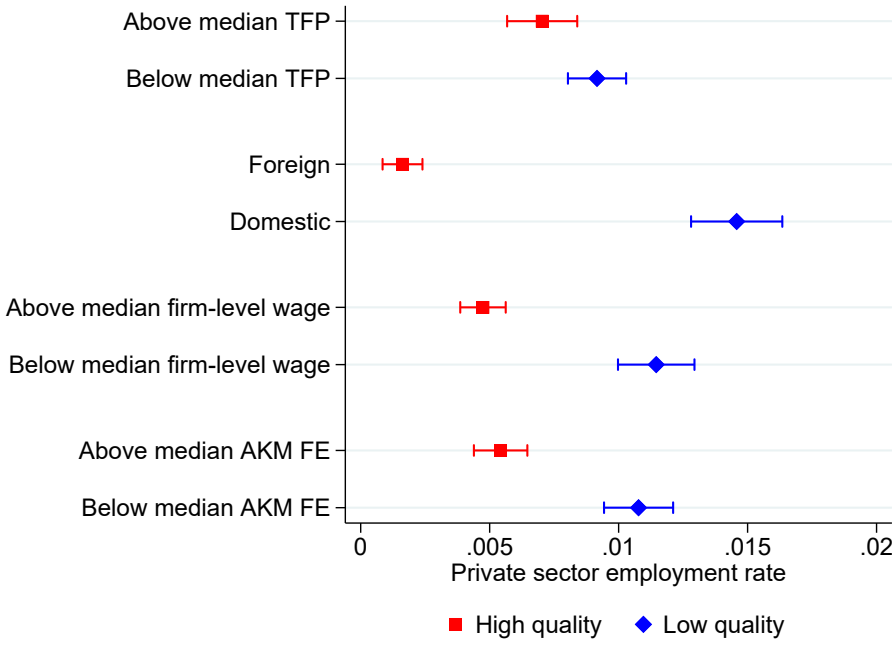


(b) Change in Private Sector Employment Rate



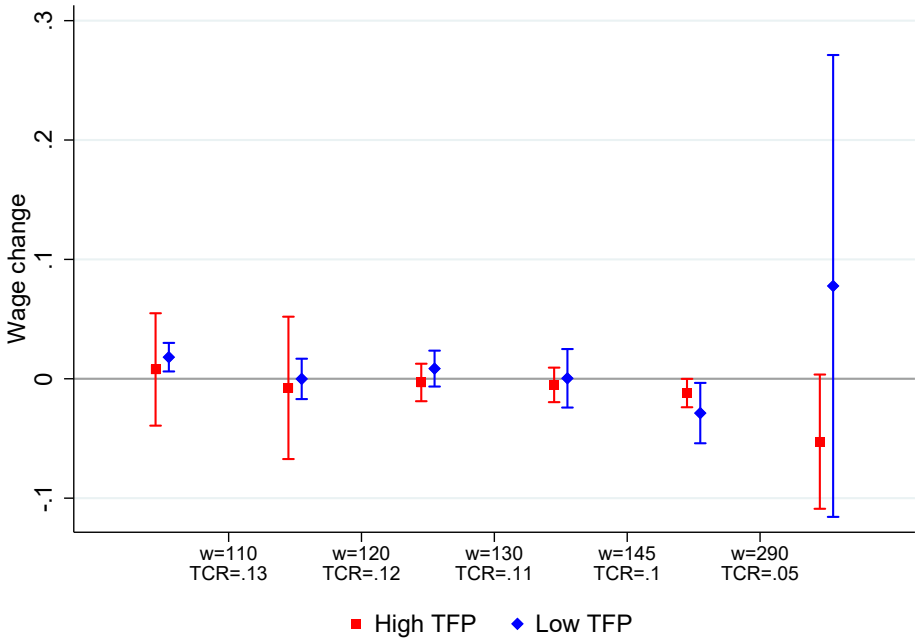
Note: Figure applies the same analysis for younger workers as Figure 3 for older workers. In particular, Panel (a) of the figure shows the private sector employment rate by age before and after the introduction of the age-specific payroll tax cut. The black line shows the employment rate in year 2012 (before the implementation of the payroll tax cut) and the gray line for years 2013-2015 (after the implementation of the payroll tax cut). Panel (b) shows the difference in employment rates between years 2012 and 2013-2015 relative to the average change between ages 25 and 40, with the 95% confidence interval (standard errors clustered at the age × period level). The vertical red line shows the age threshold where the tax cut became effective from 2013.

Appendix Figure D3: Employment in Private Sector Companies: Alternative Firm Quality Measures, Younger Workers



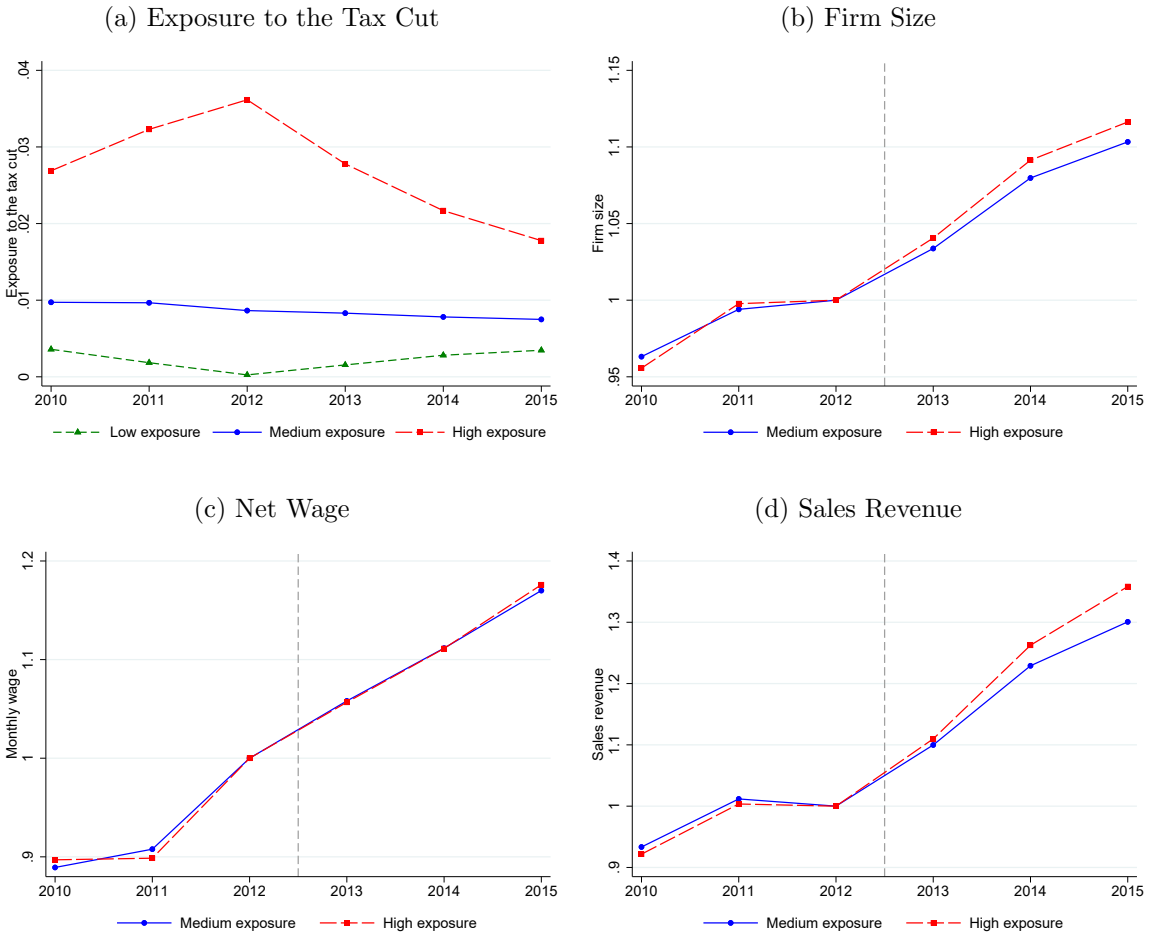
Note: Figure applies the same analysis for younger workers as Panel (a) of Figure 7 for older workers. In particular, the figure shows difference-in-differences estimates of the impact of the payroll tax cut on private sector employment based on estimating equation (9). The difference-in-differences estimate compares the change in employment among the 22 to 24 age group that was affected by the payroll tax cut with the change in employment and wages among the 25 to 27 age group that was not affected by the tax cut. The first two rows replicate our baseline results with high- and low-productivity firms. The third and the fourth rows uses foreign ownership (more than 50%) as a quality measure. In Hungary, foreign-owned firms are the most productive firms offering the highest paying, highest quality jobs. The fifth and sixth rows measure quality based on average wages, while the last two rows measure quality using the firm-level wage premium estimated using an Abowd, Kramarz, Margolis (AKM) style decomposition. 95% confidence intervals are reported with standard errors clustered at the age × period level.

Appendix Figure D4: Wage Changes at Different Levels of Lagged Wages: Younger Workers



Note: Figure applies the same analysis for younger workers as Figure 10 for older workers. In particular, figure shows difference-in-differences estimates of the payroll tax cut on private sector wages separately for low- and high-productivity (TFP) firms by lagged wage. The payroll tax cut was 14,500 HUF and so the tax cut rate, $TCR_{it-1} = 14,500/w_{it-1}$, falls as lagged wages increase. Estimates are based on a modified version of equation (13), where the linear tax cut rate TCR_{it-1} in the last interaction term is replaced with categories of the tax cut rate TCR_{it-1}. We report the cut-off values of lagged wages (in thousands of Hungarian forints) and the corresponding tax cut rates TCR_{it-1} on the x-axis of the figure. The estimates display the change in log wages among the 22 to 24 age group that was affected by the payroll tax cut relative to the change in log wages among the 25 to 27 age group that was not affected by the tax cut for above-median (in red) and below-median (in blue) TFP firms. 95% confidence intervals are reported with standard errors clustered at the age × period level.

Appendix Figure D5: Firm-level Effects of Payroll Tax Cuts of Younger Workers



Note: Figure applies the same analysis for younger workers as Figure B4 for older workers. In particular, figure replicates the basic results of Saez, Schoefer and Seim (2019). Using 2012 data, we calculate the firm-level exposure to the tax cut defined as the total tax cut based on workers aged up to 24 at the firm relative to the total payroll of the firm. We calculate the quartiles of the exposure, excluding firms with zero exposure, and group firms into three categories. "Low exposure" firms have either zero tax cut or belong to the bottom quartile. "Medium exposure" firms belong to the middle two quartiles. "High exposure" firms belong to the the top quartile. We compare the evolution of various outcomes of the firms in these groups, focusing on the medium and high exposure groups. Panel (a) shows the average exposure to the tax cut. Panel (b) shows firm size. Panel (c) shows average net wage. Panel (d) shows sales revenue.

Appendix Table D1: Elasticity of Employment: Younger Workers

	(1) All firms	(2) Low TFP	(3) High TFP
Panel A: Change in the probability of employment			
— $After \times Treated$	0.0162***	0.0092***	0.0070***
	[0.0011]	[0.0006]	[0.0007]
Panel B: Percent change in employment			
—Employment without tax cut	0.317	0.142	0.175
—Employment with tax cut	0.333	0.151	0.182
—Percent change in employment	5.11%	6.45%	4.02%
Panel C: Percent change in labor cost $(1+\tau_{ss})$			
—Labor cost without tax cut	1.25	1.23	1.26
—Labor cost with tax cut	1.17	1.15	1.18
—Percent change in labor cost	-6.61%	-7.03%	-5.96%
Panel D: Implied elasticity (Panel B/Panel C)			
— Elasticity	-0.77	-0.92	-0.67
	[0.05]	[0.06]	[0.07]

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: Table applies the same analysis for younger workers as Table 2. In particular, Panel A of the table shows difference-in-differences estimates of the impact of the payroll tax cut on private sector employment for all firms (column 1) and separately for below-median (column 2) and above-median (column 3) TFP firms in Panel A. In particular, we report the β coefficient from regression equation (9) with the outcome variable being employed at a private sector firm (column 1), at a private sector firm with below-median productivity (column 2) and at a private sector firm with above-median productivity (column 3). The β coefficient estimates the change in employment among the 22 to 24 age group that was affected by the payroll tax cut relative to the change in employment among the 25 to 27 age group that was not affected by the tax cut. Panel B calculates the percent change in employment using the difference-in-differences estimates from Panel A. The first row shows the employment rate in the treatment and control age groups in 2012, the year before the introduction of the payroll tax cut. The second row adds to that baseline the estimated change from Panel A. The third row shows the percent change in employment relative to the baseline. Panel C calculates the percent change in labor cost using an analogous difference-in-differences estimation for tax rates. Firms' labor cost is net wage times $(1+\tau_{ss})$, where τ_{ss} is the employer social security contribution. The reform cut τ_{ss} for workers in the treatment group. The first row shows the average labor cost in the control group between 2013-2015. The second row calculates the average labor cost for the treatment group taking into account the tax cut. The third row calculates the percent change in the labor cost caused by the tax cut. Panel D calculates the implied employment elasticity with respect to the wage change by taking the ratio of the percent change in employment (Panel B) and labor cost (Panel C). Standard errors are reported in brackets, clustered at the age × period level. ($N = 8,611,542$ individual-months)

Appendix Table D2: Impact on Employment by Experience: Younger Workers

	(1)	(2)	(3)
		Employment	
	All Firms	Low TFP	High TFP
All workers	0.0162***	0.0092***	0.0070***
	[0.0011]	[0.0006]	[0.0007]
	⟨0.3171⟩	⟨0.1421⟩	⟨0.1750⟩
Experienced workers	0.0110***	0.0164***	-0.0054***
	[0.0020]	[0.0011]	[0.0018]
	⟨0.4821⟩	⟨0.2311⟩	⟨0.2510⟩
Non-experienced workers	0.0221***	0.0111***	0.0111***
	[0.0012]	[0.0007]	[0.0007]
	⟨0.3002⟩	⟨0.1330⟩	⟨0.1672⟩

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: Table shows difference-in-differences estimates of the impact of the payroll tax cut on private sector employment based on estimating equation (9) for all firms (column 1) and separately for below-median (column 2) and above-median (column 3) TFP firms. We compare the change in employment among the 22 to 24 age group that was affected by the payroll tax cut with the change in employment among the 25 to 27 age group that was not affected by the tax cut. The sample is further split by working at least 6 months at ages 18-19 ("experienced" vs. "non-experienced"). The employment rate in each of these categories (relative to the total population) in May 2012 is shown in angle brackets. Standard errors are reported in brackets, clustered at the age × period level. ($N = 8,611,542$ individual-months; experienced young: $N = 707,259$ individual-months; non-experienced young: $N = 8,004,351$ individual-months.)