Using Payroll Tax Variation to Unpack the Black Box
of Firm-Level Production*

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Abstract
This paper uses quasi-experimental variation in payroll tax rates to investigate how firms use their input factors. We find that higher payroll tax rate implies relatively large employment responses and no effect on employee-level earnings. As the cost of labor increases firms substitute away from low skilled, routine and manual workers, towards more productive workers. We also find that firms decrease their investments as a response to the increased payroll tax rates. Higher firm-level payroll tax rates also slightly decrease the total output of firms. Our results imply that firm level production and input factor choices are clearly affected by payroll taxes, and that the elasticity of substitution between capital and labor is rather close to zero.

JEL Classification: H20, H22, H23.
Keywords: public economics, payroll taxes, firm behavior, incidence, redistribution.

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1 Introduction

Payroll taxes are ubiquitous: all OECD countries and most of the rest of the world impose some form of tax on payroll shared between the employer and employee and used to fund social insurance programs. And payroll tax rates can be substantial. France, for example, is known for having high income tax rates, but imposes an even higher payroll tax rate. For these reasons, payroll tax rates impose a substantial burden on the economy. The consensus in Economics is that this burden is mostly borne by workers, and therefore the price of labor faced by firms is mostly undistorted by payroll taxes. This premise has been recently questioned by Saez et al. [2012] and Saez et al. [2019].

In this paper, we investigate who bears payroll taxes and open the black box of the firm to assess how payroll taxes bias the use of factors of production. To do so, we use unique variation in the employer portion of payroll tax rates, in Finland. Finnish employers face a discontinuous increase in payroll tax rates if they exceed a set depreciation threshold. This triggers a substantial variation in payroll tax rates, which is equivalently, on average, to a 5 percentage point increase in corporate taxes. Importantly, this variation affects all employees in the firm, irrespective of their age, occupation status etc.

In doing so, we first establish that payroll taxes do not affect wages and therefore are mostly borne by firms. We then estimate the causal effect of payroll taxes on employment and find that employment is overall reduced with substantial heterogeneity by skill level and type of occupation: payroll taxes only affect low skilled workers as well workers that operate in routine tasks. We also estimate the effect of payroll taxes on investment, and find a reduction in investments, which could be either consistent with workers and capital being complements or with scale effects.

There are two main potential concerns with our empirical approach, which we address. First, regression discontinuity designs can be sensitive to functional form assumptions as well.

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1In the US, for example, the share of Federal revenue raised using payroll taxes has increased from less than 10% in the 1950’s to more than 34% in 2016. In OECD countries, they raise 26% of total tax revenue, which higher than the revenue raised by personal income taxes.
as bandwidth. We address in several ways. First, we use a placebo test that relies on years when the discontinuity in payroll taxes did not exist and estimate small and insignificant discontinuity in outcomes at the threshold. Second, we provide plots of data around the cutoff that transparently and non-parametrically show the presence of a discontinuity in our outcomes of interest. Third, we show that our estimates are not sensitive to the use of different functional forms. Fourth, we use the optimal bandwidth estimates from Calonico et al. [2014]. The second potential concern is that we might be estimating evasion responses rather than real responses. While the bunching at the threshold could be due to evasion, we are not using bunching in our estimation. Firms could also be misreporting their number of employees to avoid the additional payroll tax. While this is possible, it is extremely unlikely: while firms would be saving on payroll taxes, they would strip down employees from all possible social insurance benefits they could qualify for and they put themselves and their employees at risk of facing stiff criminal charges. Reducing wages to compensate for an increase in payroll taxes would be far less risky. Nevertheless, we implement some empirical tests of whether this could be due to evasion and find no support for this explanation.

This paper contributes to the following literatures. We contribute to the tax incidence literature in these three ways. First, since taxes are at the heart of redistribution, knowing whether they affect different skill levels differently is key to their role. We provides some of the first evidence on this question by showing that payroll taxes affect high skilled workers less than low skilled workers. Second, we show that payroll taxes tend to depress investment either through a capital-labor complementarity or because of liquidity and scale effects. This should be accounted for when scoring payroll tax changes, as is done in the US by the Congressional Budget Office (CBO).\(^2\) Third, we complement the evidence of Saez et al. [2012] and Saez et al. [2019] who show that payroll taxes are borne by firms and argue that, in their setting, this finding is likely driven by pay inequality considerations. First,

\(^2\)CBO currently assumes, as is standard in the tax incidence literature, that payroll taxes are fully borne by workers, as can be seen in this document, for example: https://www.cbo.gov/budget-options/2018/54805. This implicitly implies that payroll taxes do not distort firm level input use, which is inconsistent with our findings.
we show that, even in settings where payroll tax changes apply to all workers in a given firm, which circumvents any issues of pay inequality, payroll taxes are still borne by firms, further exacerbating the inconsistency of this finding with the canonical tax incidence model. Second, we can assess the distributional effects of payroll taxes across the skill and task spectrum, which is not implementable in Saez et al. [2019], since most 25 year olds are low skilled. Third, our variation allows us to discriminate between two possible channels through which payroll taxes affect firm level outcomes: (1) the liquidity channel, i.e., firms changing their behavior because of the liquidity constraints higher payroll taxes impose on them and (2) the marginal cost channel, i.e., firms changing their behavior because payroll taxes distort the marginal cost of labor.

Second, while there is a large body of work discussing job polarization, its effects and causes, there is very limited evidence on how taxes affect the relative distribution of workers across the skill spectrum. Our paper is the first to show that payroll taxes affect skill levels and job tasks very differently, mostly increasing employment at the top but not at the bottom. We believe this is important both because we provide an additional channel that could affect job polarization that has not been explored before and also because our findings show that payroll taxes, possibly differentiated by skill group, could be used as a policy tool to counteract job polarization.

Finally, we contribute to the literature that estimates capital-labor elasticity of substitution. The debate in this literature has mostly centered around whether the capital-labor elasticity is greater, equal or smaller than 1 when using a Constant Elasticity of Substitution (CES) production function. The consensus has been that the elasticity is equal to 1, prompting researchers to use a Cobb-Douglas production functions. More recently, this consensus has been questioned, for example, by Raval [2014] and Oberfield and Raval [2014], who estimate a capital-labor elasticity that is smaller than 1 (but larger than zero), using a CES framework. Since both capital and labor decrease when payroll taxes increase, our evidence is consistent with a capital-labor elasticity (at the micro level) that is equal to zero,
i.e., capital and labor are estimated to be complement in the CES framework. However, this decrease in both capital and labor could be consistent with liquidity effects, which are implicitly assumed away in the CES framework. For this reason, at the micro level, our findings are either consistent with capital and labor being complements or with liquidity effects dominating the capital labor substitution effect calling for the previous literature to incorporate and investigate liquidity effects.

2 Data and Institutional Background

2.1 Institutional Background

In Finland, social insurance contributions include contributions to pension schemes, unemployment insurance, accident insurance, health insurance and life insurance. Both employees and employers contribute to social insurance. The split between employees and employers depends on several firm and worker characteristics, including, for example, the age of the worker. The employer portion of social insurance contributions are based on the annual salaries paid to their employees. In general, the largest share of total social insurance contributions goes to pension contributions and the employer’s statutory share of total contributions is larger than that of their employees. For example, in 2017, the average pension insurance contribution rate was 17.95 percent of a given employee’s monthly gross wage and the employee’s contribution rate is 6.15%. In this paper, we use variation in the employer contribution rate as explained below.

Prior to 2010, there were three employers’ rate brackets for national health and pension contributions depending on their level of capital depreciation (D) and labor costs, as shown in Table 1 below. Importantly, employees’ contribution rates and benefits were not affected by these discontinuities. Category I corresponds to firms with less than 50,500 euros of annual capital depreciation (D) or more than 50,500 euros but less than 10% of annual salaries.

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3We provide details on the depreciation rules in Appendix Section A.
In addition, new firms were always subject Category I for the first two years of operation, irrespective of their depreciation levels and labor costs. Category II corresponds to firms with depreciation levels of more than 50,500 euros and 10 to 30% of labor costs. When depreciation levels exceed 50,500 euros 30% of labor costs, contributions are paid according to Category III. These categories were determined by the latest available tax information and salaries paid for the same year as the one used to determine depreciation levels. For example, the 2006 payment category was based on fiscal year 2004.

Importantly, what counts as depreciation for tax purposes can be different from what counts as depreciation for accounting purposes. Depreciation in accounting is a systematic reduction of the cost of a fixed asset and is subject to strict auditing and difficult to be manipulated. According to the Finnish tax law, the amount of annual depreciation for tax purposes cannot be larger than that for accounting purposes. This opens up a possibility for firms to manipulate the amount of annual tax depreciation, e.g. by reducing tax depreciation to qualify for a lower contribution rate. Fortunately, we have data on both of these variables and we can examine the extent to which this manipulation exists. In Appendix Figure 11 we show evidence that is much more in line with real responses rather than pure manipulation of depreciations. This is due to two empirical facts: (1) it seems that annual depreciations in accounting and taxation are very highly correlated (upper-panel of Figure 11), and (2) the excess mass of bunching firms at the threshold is very similar both in depreciations in accounting and taxation (lower-panel of Figure 11).

Employers’ contribution rates are an increasing step function of the category firms belongs to. We focus on comparing Category I to II and III. As an illustrative example, in April 2009 the national health and pension contribution rate was 2% for Category I, 4.2% for Category 2 and 5.1% for Category III. Appendix Table 8 shows the employers’ social insurance contribution rates by firm categories, for different insurance types and years.

In 2010, these firm categories were abolished and the three different contribution rates were replaced with one single rate set to be 2.23% for all firms irrespective of annual capital
Table 1: Firm categories for payroll tax rates

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<td><strong>I</strong></td>
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Note: $D$ refers to tax deductible capital depreciations and labor costs refer to all salaries.

2.2 Data

We use firm-level tax record data covering the universe of Finnish firms from 1996 to 2015, provided by the Finnish Tax Administration. The dataset contains a rich set of firm level variables and some firm characteristics including organizational form, location and industry code. The data provides yearly information, at the firm level, on labor costs, number of employees, both book (accounting) and tax amounts of capital depreciation and the level of capital investment. Importantly, with the data, we are able to separate annual investments made to three different main categories: fixed assets, buildings and research and developments. In addition, we have firm level data on sales and various cost categories, including material and rental costs.

The only data restriction we apply throughout the paper is that we exclude all firms that were not subject to the depreciation rules we consider, specifically, we remove all firms that have capital depreciation below 10% of all wages. Legally, the discontinuity in payroll tax rates we consider does not apply to these firms so there is no reason to include them in the analysis. This restriction removes approximately 25% of the total data.

In addition to the universe of firm-level data in Finland, we also observe a wide set of information on the employees of these firms, and importantly, we observe both employees and firms with their identifying variables by year, and thus are able to link these individual-level information to firms by job contracts. Employee-level data are annual data of job

\[^{4}\text{See legislation in Finlex: HE 147/2009.}\]
contracts summarizing the following variables: gender, age, working days and hours and annual earnings in each firm. These data also include the starting and ending dates for each employee-firm job contract pair. On top of this employee-level data, in a separate data set we have information about the education levels of all Finnish individuals in two forms: 1) a dummy for whether or not an employee has high school or vocational school diploma, and 2) a six category classification of the highest education level until the year of observation. We first link the job contract data, including both firm- and employee-level identification variables, to our firm-level tax register data containing the annual depreciation levels and other variables for each year. We are able to match 93.2% of all firms to their employees. Then we can link the data including education information for each employee to this data set with a match rate of 99%. Finally, we have an hourly wage rate for employees working in firms with more than five employees.

3 Empirical Strategy

To estimate the response of capital investment to labor costs, we use a discontinuity in payroll tax rates at the €50,500 depreciation threshold as described in Section 2.1. As firms cross the €50,500 depreciation threshold, the average (and marginal) payroll tax rates discontinuously increase, effectively increasing labor costs.

Our empirical strategy proceeds in three steps. First, we provide graphical evidence by plotting all our outcomes of interest around the payroll tax discontinuity and visually check that any estimated discontinuity in these outcomes is visually present.

Second, we formally estimate the size of a jump using a donut hole regression discontinuity design. Because our running variable (depreciation) can be manipulated by firms, we cannot use a standard regression discontinuity design (RDD) approach to estimate the response of capital investment to labor. Instead, we use a donut hole regression discontinuity design, as in Bajari et al. [2011], Card and Giuliano [2014] and Barreca et al. [2016]. We use the
methods from Kleven and Waseem [2013] to determine the manipulated area which, in their framework, corresponds to the area of the excess and missing masses. We describe this approach in detail in Appendix Section B.

We follow the approach of Calonico et al. [2014] to estimate the optimal bandwidth and report bias-corrected estimates with robust standard errors. In addition, we perform placebo tests by running our specification on post-2010 years when the payroll tax discontinuity was removed. Formally, we run the following regression:

\[
\log(y_i) = \alpha + \beta_1 \cdot (depr_i - d) + \beta_2 \cdot Above_i + \beta_3 \cdot Above_i \cdot (depr_i - d) + \epsilon_i
\]  

(1)

where \(y_{it}\) is the outcome of interest for firm \(i\), \(depr\) is the level of capital depreciations, \(d\) is the depreciation threshold above which the average payroll tax rate increases, \(Above\) is a dummy (1 above the depreciation threshold, 0 otherwise), \(\epsilon_i\) is error term and is calculated using the robust standard errors from Calonico et al. [2014]. \(\beta_3\) is the coefficient of interest showing the magnitude of the change of the outcome variable at the discontinuity.

Third, and to ensure that our estimates are not spurious, we run equation (1) on pre-2010 years and post-2010 years separately. The treatment years are the pre-2010 years, when the payroll tax discontinuity was in place. The post-2010 period corresponds to the placebo years, when there was no payroll tax discontinuity. As a result, the post-2010 period offers a plausible falsification test.

4 Results

In this section, we first establish that there is indeed a discontinuity in the average payroll tax due by firms. Given this discontinuity, we estimate the effect of payroll taxes on earnings first and then on employment. Finally, we consider the effect of payroll taxes on capital, as well as on other firm level outcomes (including turnover and profits).
**Payroll Tax Rate**  Figure 1 plots the average payroll tax rate for national health and pension contributions above and below the €50,500 depreciation cutoff.⁵ The average payroll tax rate exhibits a clear discontinuity at the cutoff with an increase of 2.6 percentage points. This confirms the presence of a discontinuity in payroll taxes and validates our empirical design. While seemingly small in magnitude, especially compared to other payroll tax changes analyzed for example in Saez et al. [2019], this variation is substantial because, contrary to other payroll tax incidence papers, it affects all employees at the firm. On average, it corresponds to a 5 percentage point increase in corporate taxes.

**Earnings**  Figure 2a plots the effect of the payroll tax discontinuity on individual employee earnings net of the employer portion of payroll taxes. There is no evidence of a discontinuity implying that employees above the cutoff do not appear to bear the higher payroll taxes. Using equation (1), we estimate the discontinuity in earnings at the threshold both in the treatment sample (years 1996 to 2009) and the placebo sample (years 2010 to 2015). Table 2 shows the corresponding result: we estimate a small and insignificant response of earnings in both the treatment and placebo samples of -0.003 and -0.034, respectively.

**Total Labor Costs**  Next, we consider the effect of the payroll tax rate discontinuity on total labor costs at the firm level. Total labor costs corresponds to the total amount spent by a firm on their employees and is net of the employer and employee portion of payroll taxes. Figure 2b plots the response of labor costs to the discontinuity. We observe a decrease in labor costs just above the cutoff, implying that net of payroll taxes labor costs are decreased as payroll taxes increase. This is confirmed by the regression estimates that show a 14.4% reduction in labor costs. The corresponding placebo estimate is 0.3%.

Since we have estimated that earnings do not respond to the payroll tax, but labor costs do, and since labor costs are roughly the product of earnings and number of employees, this

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⁵As shown in Appendix Table 8 A, this variation only applies to the national health and pension contribution rates which only determines a fraction of total firm-level contributions.
implies that employment must respond to the payroll tax discontinuity. Next, we estimate the effect of the discontinuity on employment.

**Employment**  Figure 2c confirms that the labor costs response is mostly due to a decrease in employment (rather than a decrease in earnings): as payroll taxes increase, the number of employees at a given firm decrease. We estimate a -8.1% response to the payroll tax, as show in column (3) of Table 2.

This finding is important and contrasts with the traditional view of the real effect of payroll taxes on wages and employment. Since the common wisdom is that payroll taxes do not affect the price of labor faced by firms, since they are passed through to wages, because labor demand is more elastic than labor supply, we usually do not expect payroll taxes to have employment effects. The fact that payroll taxes distort employment is also consistent with the findings from Saez et al. [2019] who show that, as payroll taxes are cut for workers younger than 25, firms tend to employ more of them. We complement their compelling findings in two ways: (1) we establish that these employment effects exist even when across the board payroll taxes changes are implemented, mitigating concerns that these employment effects may be due to the pay inequality concerns of paying a 25 year old a different wage than a 26 year old and (2) we can assess the distributional effects of payroll taxes across the skill and task spectrum, which is not implementable in Saez et al. [2019], since most 25 year olds are low skilled.

These estimated employment effects indeed mask important dimensions of heterogeneity along skill levels but also along the type of task workers engage in. We describe both below in detail.

**Employment effects along the skill dimension**  While the labor economics literature has devoted substantial attention to the importance of skills in the labor market, our knowl-
edge of the differential effects of taxes by skill level is still limited in public finance.\footnote{See the following for examples of the labor market importance of skills Card and Lemieux [2001], Carneiro and Lee [2011], Katz and Murphy [1992], Goldin and Katz [1998] and Krusell et al. [2000]}. In order to investigate this response, we break down our sample of workers into high versus low skilled. The skill breakdown is based on educational attainment, as is commonly done in the skill literature. In the Finnish education system, there are two main levels of academic achievements: graduating from high school and graduating from college. We perform our classification using these two metrics. Our first breakdown classifies workers without a high school degree as low skilled, and those with a high school degree as high skilled. The second classification, draws the skill line at graduating from college. Figure 3 show the employment effects of payroll taxes for these four groups. We detect no employment effects for high skilled workers, whether defined by college or high school graduation, as shown in Figure 3 panels c and d. Instead, all the effects seem concentrated on low skilled workers, as shown in Figure 3 panels a and b.

The graphical evidence is confirmed by our regression estimates in Table 3 that show: the employment response for low skilled workers is -10.9% or -8.9%. For high skilled workers instead, it is 2.7% and statistically insignificant. The placebo tests (years 2010 to 2015) show no response for either low skilled or high skilled workers.

**Employment effects along the task dimension** A more recent literature has been arguing that the low skilled/high skilled categorization masks important heterogeneity and a better suited categorization is one centered around job tasks, as surveyed in Acemoglu and Autor [2011].\footnote{See also Akerman et al. [2015], Acemoglu and Restrepo [2018], Autor et al. [2003], Hershbein and Kahn [2018], David and Dorn [2013] and Goos et al. [2014].} Following this literature and using the data on employee demographics and job descriptions, we categorize workers into three groups: (1) upper level employees, which include senior officials and upper management, senior officials and employees in research and planning, senior officials and employees in education and training and other senior officials and employees; (2) which include supervisors, clerical and sales workers and other lower-level
employees; and (3) Routine and manual workers, which include clerical and sales workers, routine worker, workers in agriculture, forestry and commercial fishing, manufacturing workers, distribution and service workers and Other production workers.

Figure 4 plots the employment response for these three groups. The negative employment response is clearly concentrated among the routine and manual workers. There is no substantial response for non-manual, non-routine lower level workers and we observe an increase in upper level workers.

**Investment** If the firm production function is such that capital and labor are substitutes then the employment effects we estimate should result in an increase in investment to substitute for the decrease in labor. On the other hand, if capital and labor are complements, a decrease in employment should result in a decrease in investment. It is worth noting that this logic abstracts away from any liquidity effects: if liquidity effects are larger than substitution effects, an increase in the price of labor will lead to an increase in both capital and labor even if capital and labor are substitutes. We return to this point below in Section 5.

Figure 5 shows the effect of the payroll tax discontinuity on investment. Figure 5 panel a shows that total investment decreases as a result of the higher payroll taxes. This decrease in total investment is driven by a decrease in fixed asset investments, as shown in panel b of Figure 5. We do not observe any change in buildings, as shown in panel c of Figure 5. And we observe an increase in RD investment, as shown in panel d of Figure 5.

Table 5 provides the corresponding estimates. We estimate a decrease of 15.0% for total investment, which is mostly driven by the 18.2% decrease of fixed assets. The corresponding estimate for RD investment is 18.0% increase, and statistically insignificant change in buildings. The corresponding placebo estimates, show small and insignificant effects for investment and fixed assets.

**Sales and productivity** Given that firms decrease both capital and labor as a response to the increase in payroll taxes, one could reasonably expect a decrease in sales. The upper
panel of Figure 6 plots the response of sales. The discontinuity at the threshold is negative, but small. We estimate a response of -4.6% (relative to a placebo of -2.0%), implying that the volume of sales, while it responds negatively as one would expect, exhibits a very limited response.

This could be consistent with an increase in productivity, which would also be consistent with the fact that we estimate a decrease in less productive workers, ie manual and routine workers, as well as low skilled workers. In Figure 6, we plot the response of total factor productivity, which is a commonly used measure of productivity. We find that TFP is indeed discontinuous at the threshold. In Table 6 we estimate that TFP increases by 11.9%, relative to a placebo estimate of -0.1%.

These results suggest that firms are mitigating the effects of the higher payroll tax rates, by scaling down on the less productive factors of production.

5 Implications for Firm Level Production

Wages are downwards rigid  This is a finding that has been widely discussed in the labor economics literature.\(^8\) Notably, Card [1990], shows that nominal wage rigidity leads to employment effects at the firm level. Yet, in spite of this large literature documenting the existence of wage rigidity, there is limited evidence of wages not responding to payroll tax increases and the consensus in public finance is still that the incidence of payroll taxes is fully borne by workers.

In principle, in our setting, wages could be rigid because of the prevalence of collective wage agreements in Finland. These agreements set the industry level minimum wage, but otherwise allow wages to vary flexibly. Therefore, they could explain why payroll taxes are be fully borne by firms, but only for employees earning the collective bargained minimum wage. In Figure ??, we test whether earnings of top earners respond to payroll taxes and

\(^8\)See, for example, Akerlof et al. [1996], Kahn [1997], Card and Hyslop [1997], Dickens et al. [2007], Barattieri et al. [2014].
find that they do not, suggesting that collective wage agreements cannot explain that payroll
taxes are borne by firms, at least for non-minimum wage earning workers.

What explains downwards wage rigidity? While this falls out of the scope of this paper,
several explanations have been put forward, including, more recently, explanations based on
fairness and norms. Kaur [Forthcoming], for example, shows, using a survey of farm workers
in India, that fairness considerations a la Kahneman et al. [1986] are likely to explain wage
rigidity.

Interestingly, we find that belonging to a labor union has limited employment effects
as shown in Figure 7. In other words, the employment responses seem to be very similar
whether or not employees belong to a labor union or not. This could be due to three reasons:
(1) labor unions tend to represent everyone, irrespective of whether an employee actually
contributes or (2) the employment effects are not driven by employees being fired but instead
by fewer employees being hired. We believe both could be at play here.

**At the micro level, we estimate that labor and capital are complements.** When
assuming a CES production function, our results imply a micro KL elasticity of substitution
that is equal to zero. We derive these predictions in Appendix Section C, but the intuition
for this result is straightforward. If the elasticity of substitution between capital and labor
is positive, then when labor decreases (after payroll taxes increase), capital should increase,
as firms substitute away from labor towards capital. Instead, we estimate that, as labor
decreases, so does capital, which implies that the two are complements in the CES framework
and that the micro-level capital-labor elasticity of substitution must be zero, i.e., that the
production function is Leontief.

There are very few estimates of firm-level capital-labor elasticity of substitution. Two
notable exceptions are Raval [2014] and Oberfield and Raval [2014], who estimate the capital-
labor elasticity of substitution using micro data by relying on cross-sectional variation in local
wages. Oberfield and Raval [2014] also offers a framework to aggregate micro elasticities into
macro elasticities. Both papers estimate a capital-labor elasticity of substitution below one (but well above zero).

Our paper provides one such estimates. Our estimate is far away from the macro estimate, and while Houthakker [1955] shows that even micro level Leontief production functions can be aggregated to CES with KL elasticity greater than 1, we use the aggregation framework from OR (2014) to show that the implied macro level KL elasticity is far smaller than 1. In principle, this could cast doubt on Piketty’s argument that the fall in labor shares is likely driven by a KL elasticity greater than 1.

However, empirically, the positive correlation between capital and labor could also be consistent with liquidity effects being larger than substitution effects, which we explore below.

**Liquidity Effects** Are liquidity constraints binding? In spite of this question being seemingly simple, there is no clear empirical answer to it. Modigliani and Miller [1958] predict that, with no differential costs of internal and external financing, firms should not face substantial liquidity constraints. On the other hand, if external financing is more costly than internal financing – possibly because of asymmetric information or incomplete contracting – cash injections should have a positive effect on capital expenditures. Rauh [2006], for example, uses a regression kink design at the pension funding threshold below which firms have to spend extra cash to ensure that their pensions are funded and finds that additional cash generated by the pension funding threshold affects capital expenditures but acknowledges the possibility that external financing costs might be different discontinuously different above and below the pension funding cutoff inflating the magnitude of the response. Another example is Blanchard et al. [1994] who analyze the response of a sample of eleven firms to winning monetary payments from lawsuits and find no effect on capital expenditures, consistent with the prediction from Modigliani and Miller [1958].

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9Saez et al. [2019] acknowledge that the firm level effects of payroll taxes they estimate are the combined effect on business activity of both cash windfalls and factor price changes. Because of their empirical design,
Using our empirical design, we can investigate whether payroll taxes impose substantial liquidity constraints on firms by implementing several different empirical tests. First, as argued above, the positive correlation between labor and capital could be consistent with (1) labor and capital being complements or (2) labor and capital being substitutes and liquidity effects outweighing substitution effects. A simple test can allow us to disentangle these two explanations: if labor and capital are complements, then we should observe a constant labor to capital ratio above and below the payroll tax discontinuity. Figure 8 shows no clear change in the labor to capital ratio as payroll taxes increase, implying that labor-capital complementarity could explain our findings.

However, if capital-labor complementarity would entirely explain our results, we should not observe a decrease in turnover as payroll tax rate increase. Yet, this is what we find in the upper panel of Figure 6, which shows that sales decrease by 4.6%. However, this effect is small, and very close to the estimated placebo effect (2.2%). This could be due to the estimated increase in productivity, as shown in the lower panel of Figure 6, which shows a substantial increase in TFP, which could have mitigated the decrease in turnover.

6 Conclusion

In this paper, we use quasi-experimental variation in payroll taxes to investigate how firms use their input factors. We have several interesting findings: as the cost of labor increases (1) firms substitute away from low skilled, routine and manual workers, towards more productive workers, (2) firms decrease investments and (3) sales slightly decrease while productivity increases.

Our results have important implications for our understanding of firm level production and input factor choices. First, our findings are inconsistent with large micro level substitution between capital and labor, or at the very least larger than liquidity effects. Second, our results which compares labor intensive versus capital intensive firms, they cannot disentangle the two effects.
highlight the importance of accounting for heterogeneity in skill level and job tasks when estimating the incidence of payroll taxes. Third, from a policy perspective, our estimates imply that payroll taxes impose a negative fiscal externality on several other fiscal bases as they reduce capital but also sales and profits. This effect should be taken into account when the governments score payroll tax changes.

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Figure 1: Payroll Tax Rate

(a) Treatment Years (1996-2009)

Notes: This Figure plots the average payroll tax rates above and below the capital depreciation threshold for national health and pension contributions. The second panel shows a placebo test for years 2010 to 2015 for the same variable.
Notes: The first panel shows the response of earnings per employee (in logs) at the payroll tax discontinuity. The second panel shows the response of net of payroll taxes total labor costs paid by firms to the payroll tax discontinuity. The years included are 1996 to 2009.
Figure 3: Employment Effects by Skill Level

Notes: These Figures plot the (log) number of employees with lower than secondary education (first panel), with no high school diploma (second panel), with higher than secondary education (third panel) and with a high school degree in firms around the capital depreciation threshold.
Figure 4: Employment Effects by Job Task

Notes: These Figures plot the (log) number of employees with upper- and lower-level tasks (first and second panels) and with manual tasks in firms around the capital depreciation threshold (third panel).
Figure 5: Effects on Investments

Notes: These Figures plot the (log) total annual investments of firms (first panel), and total investments divided to fixed assets (second panel), buildings (third panel) and R&D (fourth panel) around the capital depreciation threshold.
Figure 6: Production and Productivity

Notes: Figures plot the (log) sales (first panel) and total factor productivity (second panel) of firms around the capital depreciation threshold.
Figure 7: Employment by Unionization Status

Notes: These Figures plot the (log) number of non-union employees, employees paying unemployment insurance payments but not belonging to a union (fake union) and employees belonging to a labor union around the capital depreciation threshold.
Figure 8: Liquidity Test

Notes: This Figure plots the share of labor costs divided by the capital stock around the capital depreciation threshold.
Table 2: Effects on Earnings and Number of Employees

<table>
<thead>
<tr>
<th>Outcomes (logs)</th>
<th>Earnings</th>
<th>Labor Costs</th>
<th>No. Employees</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Treatment</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RD Estimate</td>
<td>-0.003</td>
<td>-0.144***</td>
<td>-0.081***</td>
</tr>
<tr>
<td></td>
<td>(0.007)</td>
<td>(0.036)</td>
<td>(0.030)</td>
</tr>
<tr>
<td>Observations</td>
<td>103,176</td>
<td>115,263</td>
<td>119,607</td>
</tr>
</tbody>
</table>

| **Placebo**    |          |             |               |
| RD Estimate    | -0.034   | 0.003       | 0.067         |
|                | (0.021)  | (0.047)     | (0.038)       |
| Observations   | 55,798   | 56,367      | 64,101        |

*Notes:*

Table 3: Effects by Skills

<table>
<thead>
<tr>
<th>Log No. Employees</th>
<th>High School</th>
<th>No High School</th>
<th>Secondary or Higher</th>
<th>Lower Than Secondary</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Treatment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RD estimate</td>
<td>0.027</td>
<td>-0.109***</td>
<td>0.027</td>
<td>-0.089***</td>
</tr>
<tr>
<td></td>
<td>(0.027)</td>
<td>(0.028)</td>
<td>(0.023)</td>
<td>(0.028)</td>
</tr>
<tr>
<td>Observations</td>
<td>110,149</td>
<td>110,149</td>
<td>110,149</td>
<td>110,149</td>
</tr>
</tbody>
</table>

| **Placebo**       |             |                |                     |                     |
| RD estimate       | 0.030       | 0.042          | 0.025               | 0.033               |
|                   | (0.032)     | (0.036)        | (0.027)             | (0.035)             |
| Observations      | 63,525      | 63,525         | 63,525              | 63,525              |

*Notes:*

Table 4: Effects by Tasks

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Treatment</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RD estimate</td>
<td>0.112***</td>
<td>-0.012</td>
<td>-0.099***</td>
</tr>
<tr>
<td></td>
<td>(0.033)</td>
<td>(0.034)</td>
<td>(0.029)</td>
</tr>
<tr>
<td>Observations</td>
<td>57,679</td>
<td>69,173</td>
<td>81,201</td>
</tr>
</tbody>
</table>

| **Placebo**    |                         |                         |                   |
| RD estimate    | -0.041                  | 0.050                   | 0.061             |
|                | (0.148)                 | (0.171)                 | (0.162)           |
| Observations   | 64,101                  | 64,101                  | 64,101            |

*Notes:*
Table 5: Effect on Firm Outcomes

<table>
<thead>
<tr>
<th>Outcomes (logs)</th>
<th>Investment</th>
<th>Fixed assets</th>
<th>Buildings</th>
<th>R&amp;D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RD Estimate</td>
<td>-0.150***</td>
<td>-0.182***</td>
<td>0.113</td>
<td>0.180**</td>
</tr>
<tr>
<td></td>
<td>(0.041)</td>
<td>(0.042)</td>
<td>(0.089)</td>
<td>(0.088)</td>
</tr>
<tr>
<td>Observations</td>
<td>107,542</td>
<td>104,171</td>
<td>49,038</td>
<td>51,529</td>
</tr>
<tr>
<td>Placebo</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RD Estimate</td>
<td>0.058</td>
<td>0.013</td>
<td>0.088</td>
<td>0.129</td>
</tr>
<tr>
<td></td>
<td>(0.058)</td>
<td>(0.060)</td>
<td>(0.141)</td>
<td>(0.156)</td>
</tr>
<tr>
<td>Observations</td>
<td>54,008</td>
<td>51,055</td>
<td>26,715</td>
<td>24,382</td>
</tr>
</tbody>
</table>

Table 6: Effect on Firm Production Measures

<table>
<thead>
<tr>
<th>Outcomes (logs)</th>
<th>Turnover</th>
<th>Inputs</th>
<th>Markup</th>
<th>TFP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RD estimate</td>
<td>-0.046*</td>
<td>-0.276*</td>
<td>-0.017</td>
<td>0.119***</td>
</tr>
<tr>
<td></td>
<td>(0.028)</td>
<td>(0.153)</td>
<td>(0.057)</td>
<td>(0.027)</td>
</tr>
<tr>
<td>Observations</td>
<td>118,041</td>
<td>119,607</td>
<td>86,796</td>
<td>113,288</td>
</tr>
<tr>
<td>Placebo</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RD estimate</td>
<td>-0.020</td>
<td>0.014</td>
<td>0.005</td>
<td>-0.001</td>
</tr>
<tr>
<td></td>
<td>(0.042)</td>
<td>(0.128)</td>
<td>(0.061)</td>
<td>(0.032)</td>
</tr>
<tr>
<td>Observations</td>
<td>63,276</td>
<td>64,101</td>
<td>59,007</td>
<td>55,725</td>
</tr>
</tbody>
</table>

Table 7: Role of Unions

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>Share of union employees</th>
<th>No. not union employees</th>
<th>No. fake union employees</th>
<th>No. union employees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RD estimate</td>
<td>0.004</td>
<td>-0.059***</td>
<td>-0.050**</td>
<td>-0.052**</td>
</tr>
<tr>
<td></td>
<td>(0.007)</td>
<td>(0.026)</td>
<td>(0.025)</td>
<td>(0.023)</td>
</tr>
<tr>
<td>Observations</td>
<td>93,566</td>
<td>119,607</td>
<td>119,607</td>
<td>119,607</td>
</tr>
<tr>
<td>Placebo</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RD estimate</td>
<td>-0.003</td>
<td>0.044</td>
<td>0.051*</td>
<td>0.014</td>
</tr>
<tr>
<td></td>
<td>(0.010)</td>
<td>(0.032)</td>
<td>(0.031)</td>
<td>(0.026)</td>
</tr>
<tr>
<td>Observations</td>
<td>64,101</td>
<td>64,101</td>
<td>64,101</td>
<td>64,101</td>
</tr>
</tbody>
</table>
A Depreciation Rules

The Finnish tax authorities’ definition of capital is any fixed assets which include all long-term tangibles that firms are using in their production process to generate income that cannot easily be converted into cash such as land, buildings, machinery, stocks, equipment, vehicles, leasehold improvements, and other such items. Firms can choose their depreciation rules: (1) linear depreciation with the same euro value per year, or (2) double declining balance depreciation with the same percentage per year. In Finland, buildings, other constructions, machinery and equipment are all depreciated using the declining balance method. There are also different depreciation rules and percentages for different asset types. Depreciation for each building is calculated separately, with the maximum depreciation percentage varying from 4% to 20%, depending on the type of construction. For example, the annual depreciation rate for office buildings is 4%, 7% for factory buildings and 25% for immovable capital. The maximum rate of depreciation of machinery and equipment is 25%.

The life of assets can vary depending on the type of asset type that directly affects the amount of depreciation. Assets with a useful life of less than three years may be written off using the free depreciation method, i.e. deduct up to 100% of the costs of assets in a single tax year where the value for each item is less than 850 euros and the total value of such assets is no more than 2,500 euros per tax year. Patents and other intangible rights, such as goodwill, are amortized on a straight-line basis for ten years, unless the taxpayer demonstrates that the asset has a shorter useful life.

B Bunching Methodology

We follow Chetty et al. [2011] and Kleven and Waseem [2013] to estimate the magnitude of bunching. First, we construct the counterfactual density by excluding the “distorted distribution” close to the observed distribution, and then fit a flexible polynomial function using the undistorted distribution.

We begin by constructing a bin sample. We divide the data into 100 euros bins and count the number of firms in each bin. Then we estimate a counterfactual density by running the following regression while excluding the region around the threshold \([D_L, D_H]\):

\[
c_j = \sum_{i=0}^{p} \beta_i(D_j)^i + \sum_{i=D_L}^{D_H} \eta_i \cdot 1(D_j = i) + \varepsilon_j
\]  (2)
where \( c_j \) is the count of firms in bin \( j \), \( D_j \) denotes the depreciation in bin \( j \) and \( p \) is the order of the polynomial. Therefore, the estimated values for the counterfactual density are 
\[
\hat{c}_j = \sum_{i=0}^p \beta_i (D_j)^i.
\]
We can calculate the excess bunching by comparing the actual number of firms just below the threshold (within \((D_L, D^*)\)) to the estimated counterfactual density within the same region:
\[
\hat{b}(D^*) = \frac{\sum_{i=D_L}^{D^*} (c_j - \hat{c}_j)}{\sum_{i=D_L}^{D^*} \hat{c}_j / N_j}
\]
where \( N_j \) represents the number of bins within \([D_L, D^*]\).

As is common in the bunching literature, we define the lower limit of the excluded region \((D_L)\) simply based on visual observations, representing the point where bunching begins.

We follow the approach of Kleven and Waseem [2013] to define the upper limit and thus the marginal buncher firm \( D_H \). This point is determined such that the estimated excess mass equals the estimated missing mass above the threshold \( D^* \). In practice we do this using an iterative process which starts with a small \( D_H \) and converges when the excess mass is equal to the missing mass, i.e., \( \hat{b}_E(y^*) \approx \hat{b}_M(y^*) \).

Finally, we calculate standard errors by using a residual-based bootstrap procedure. We first generate a large number of depreciation distributions by randomly resampling the residuals from equation (2) with replacement. Then based on the resampled distributions, we estimate a large number of counterfactual densities. In the bootstrap procedure, we also take into account the iterative process to determine the marginal buncher. Based on these bootstrapped counterfactual densities, we evaluate variation in the estimates of interest. The standard errors for each estimate are defined as the standard deviation in the distribution of the estimate.

\section{C Capital-Labor Elasticity of Substitution: Conceptual Framework}

\subsection{C.1 Micro Capital-Labor Elasticity of Substitution}

\textbf{Production Function.} We assume that firms exhibit constant elasticity of substitution (CES) production functions as follows:
\[
F(k, l) = (\alpha k^{\frac{\sigma-1}{\sigma}} + (1 - \alpha) l^{\frac{\sigma-1}{\sigma}}) \frac{\sigma}{\sigma-1},
\]
where \( k \) is capital, \( l \) is labor, and \( \alpha \) and \( \sigma \) are parameters. \( \sigma \) is assumed to be strictly
positive and has no upper bound. When $\sigma \to 0$, it can be shown that the production function
is Leontief with the following form:

$$F(k, l) = \min(k, l).$$

Denote by $\epsilon_{k,l}$ the elasticity of substitution between capital and labor and by RTS the rate
of technical substitution between capital and labor. It can be shown that the capital-labor
substitution elasticity only depends on $\sigma$:

$$\epsilon_{k,l} = \frac{d (k/l)}{d(RTS)} \frac{RTS}{k/l} = \frac{d (k/l)}{d (-F_l/F_k)} \frac{-F_l/F_k}{k/l} = \sigma.$$  

Next, since we are interested in how capital and labor respond to changes in payroll taxes,
we derive the demands for labor and capital by minimizing the cost function subject to a
production level constraint. We assume $\sigma > 0$ throughout and return to Leontief production
functions below. Formally, we solve the following minimization problem for $\sigma > 0$, where $w$
is wage and $r$ is the cost of capital:

$$\min_{k,l} C(w, r) = w l + r k$$
subject to

$$F(k, l) = q_0$$

This yields the following condition:

$$k = \left(\frac{w}{r} \frac{\alpha}{1 - \alpha}\right)^\sigma l$$

Using this relationship and the resource constraint $F(k, l) = q_0$, we get:

$$l = q_0 \left( \alpha \left( \frac{w}{r} \frac{\alpha}{1 - \alpha} \right)^{\sigma - 1} + (1 - \alpha) \right)^{\frac{\sigma}{\sigma - 1}},$$

$$k = q_0 \left( (1 - \alpha) \left( \frac{w}{r} \frac{\alpha}{1 - \alpha} \right)^{1 - \sigma} + \alpha \right)^{\frac{\sigma}{\sigma - 1}}.$$

We take the derivative of these two equations with respect to $w$ to get the elasticity of
capital and labor with respect to wage:

$$\epsilon_{k,w} = \frac{\partial k}{\partial w} \frac{w}{k} = \frac{(1 - \alpha)\sigma}{(1 - \alpha) + \alpha \left( \frac{w}{r} \frac{\alpha}{1 - \alpha} \right)^{\sigma - 1}}.$$
These two expressions imply that firms with CES production functions with $\sigma > 0$ will increase capital when wages decrease and decrease labor when wages increase. Empirically, firms with CES production functions would respond to labor cost changes by decreasing their number of employees and increasing their capital investment to replace workers.

**Leontief Production Function.** Leontief production functions are a special case of CES production functions: it can be shown that when $\sigma \to 0$, i.e. the capital-labor supply elasticity tends to zero, which means that capital cannot be substituted with labor and vice-versa, $F(k, l) = \min(\alpha k, \beta l)$. In this case, labor and capital are used in equal shares. For this reason, when the cost of labor increases, both the demand for labor and for capital decrease. This implies that when the capital-labor elasticity of substitution is zero, both $\epsilon_{k, w}$ and $\epsilon_{l, w}$ will be negative. Empirically, when labor costs increase, firms with Leontief productions functions reduce both their number of employees and their investment in capital since both inputs are used in fixed proportions.

**A Simple Empirical Test of Leontief versus CES Production Functions.** The derivations above imply a simple test of whether $\epsilon_{k, l}$ is strictly positive or zero: estimating the response of capital flows, i.e., investments, to labor cost changes. If investments *increases* when labor costs increase, then $\epsilon_{k, l} > 0$. If instead, investments *decreases* when labor costs increase then $\epsilon_{k, l} = 0$. In the rest of the paper, we setup our empirical framework to estimate how investments respond to changes in labor costs.

**D Macro Elasticities**

The capital-labor elasticity of substitution we have estimated is a micro elasticity and does not account for possible substitution across different firms and or industries. However, we can use our micro elasticity to derive an estimate of the macro elasticity by relying on the framework of Oberfield and Raval [2014]. The authors show that the aggregate elasticity of substitution is a weighted average of the micro elasticity of substitution and the elasticity of demand.

Formally, given the following production function: $F(k, l) = (\alpha k^{\frac{\sigma - 1}{\sigma}} + (1 - \alpha)l^{\frac{\sigma - 1}{\sigma}})^{-\frac{1}{\sigma - 1}}$, We denote by $\alpha_i = \frac{r_k}{r_k + w_l}$ and $\alpha = \frac{r_k}{r_k + w_l}$ the capital share in the total costs of production for firm $i$ and the aggregate capital share, respectively. Further, we define $\theta_i$ to be plant $i$’s
cost of labor and capital as a share of the aggregate costs of labor and capital. Oberfield and Raval [2014] show that the macro capital-labor elasticity of substitution $\sigma^{agg}$ is a weighted average of the micro elasticity of substitution and the elasticity of demand $\varepsilon$:

$$\forall \sigma \geq 0, \; \sigma^{agg} = (1 - \chi)\sigma + \chi\varepsilon$$  \hspace{1cm} (3)$$

where $\chi = \sum_{i \in I} (\alpha_i - \alpha)^2 / \alpha(1 - \alpha) \theta_i$ represents the degree of heterogeneity in the relative use of labor and capital in a given market and $I$ is the total number of firms. $(1 - \chi)\sigma$ measures the substitution of labor with capital within a given plant as a response to changes in relative factor prices and $\chi\varepsilon$ measures the reallocation effect of labor and capital across firms when relative factor prices change: for example, when the cost of capital increases, firms that rely more heavily on labor gain a cost advantage that they can pass through to prices. The elasticity of demand $\varepsilon$ determines the extent to which consumers respond to lower prices by shifting consumption to the labor intensive commodity.

$\alpha_i$, $\alpha$ and $\theta_i$ are directly observable in the corporate tax data, which reports both labor and capital costs. To estimate $\varepsilon$, we use the average markup $\mu$ and assume that $\varepsilon = 1/\mu$. We follow Antras et al. [2017] and define markups as $\frac{\text{sales} - \text{costs}}{\text{costs}}$.

We estimate that $\chi = 0.13$ and $\varepsilon = 1.29$. These estimates imply a macro capital-labor elasticity of substitution $\sigma^{agg} = 0.17$. 

Notes: The first panel shows the response of the number of employees (in logs) at the payroll tax discontinuity from 1996 to 2009. The second panel shows a placebo test for years 2010 to 2015 for the same variable.
Figure 10: Smaller Bin Width.

Notes: The first panel shows the response of the number of employees (in logs) at the payroll tax discontinuity from 1996 to 2009. The second panel shows a placebo test for years 2010 to 2015 for the same variable.
Notes: These Figures compare tax depreciation to accounting depreciation measures. The first panel plots the distribution of the difference between tax and accounting depreciation for firms that bunch at the threshold and firms that do not. The second and third panel shows the distribution of tax and accounting depreciation, respectively, in the neighborhood of the payroll tax discontinuity.
Table 8: Social insurance percentages by firm categories, different insurance types and years

<table>
<thead>
<tr>
<th>Year</th>
<th>National health and pension</th>
<th>Unemployment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Firm categories*</td>
<td>Accident</td>
</tr>
<tr>
<td></td>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td>1996</td>
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<td>5.600</td>
</tr>
<tr>
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<td>4.000</td>
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<td>5.600</td>
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<td>4.201</td>
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<td>2.220</td>
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<td>2.080</td>
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<td>2016</td>
<td>2.120</td>
<td>2.120</td>
</tr>
<tr>
<td>2017</td>
<td>1.080</td>
<td>1.080</td>
</tr>
</tbody>
</table>

* Refers to firm categories by wage sums and capital depreciation.
** Category I is for wages below certain wage sums threshold, e.g. 2,059,500 euro in year 2017, and category is for wages above the threshold. The threshold varies over years.
*** Represents the average values of these insurances.