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DISCUSSION PAPER SERIES 192/26

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www.rfberlin.com JULY 2026

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Reference

JEL Codes: J23, J32, H25, H32, O31, O32

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Recommended Citation: Hyejin Ku, Uta Schönberg, Ragnhild C. Schreiner (2026): Taxing Labor: Firm R&D, Automation and the Labor Share. RFBerlin Discussion Paper No. 192/26

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Taxing Labor: Firm R&D, Automation and the Labor Share*

Hyejin Ku† Uta Schönberg‡ Ragnhild C. Schreiner§

Abstract: This paper provides new micro-level evidence on how labor taxation shapes firm behavior, exploiting an EU-mandated payroll tax reform in Norway. Combining administrative and survey data, we find that firms facing larger tax increases sharply cut employment but also increased R&D spending, implemented labor cost-saving innovations, and adopted more automation. While these responses led to improvements in labor and total factor productivity within the firm, the firm's labor share fell. These effects persisted even after the tax hike was unexpectedly reversed three years later, suggesting a lasting shift toward more capital-intensive production in response to higher labor costs.

Keywords: payroll taxes, labor costs, firm behavior, technology adoption, inequality
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* We thank David Autor, Manudeep Bhuller, Christian Dustmann, Ed Glaeser, Larry Katz, Attila Lindner, Jonas Loebbing, Magne Mogstad, Amanda Pallais, Raffaele Saggio, Anna Salomons, Ben Schoefer, Sebastian Siegloch, Juan Carlos Suárez Serrato, and seminar/conference participants at CEPR-Bank of Italy, CESifo, Cologne, CUHK, EALE, Econometric Society China Meeting (Hangzhou), Harvard, HKU, Institute for Employment Research (Nuremberg), LMU Munich, the Nordic Public Policy Symposium, the Bank of Norway, Seoul National University, VATT, and the 3rd Oslo Public-Labor workshop, for helpful comments and suggestions. The support of the Economic and Social Research Council (ESRC), under Grant Ref: ES/R005745/1, is gratefully acknowledged. Schreiner gratefully acknowledges funding from the Norwegian Research Council (grant number 335380 and 341250).
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1. Introduction

As robots and AI systems take on an ever-wider range of tasks, workers increasingly worry about displacement and widening income inequality. Yet not all automation is alike. Acemoglu and Restrepo (2019) distinguish "so-so" automation, which displaces workers with little productivity gain, from productivity-enhancing automation, which raises productivity sharply and creates new tasks in which labor has a comparative advantage. Building on this distinction, Acemoglu et al. (2020) argue that the U.S. tax system's bias in favor of capital over labor encourages excessive automation of the "so-so" kind. The broader implication is that automation is shaped not only by technology but by policy—particularly the relative taxation of capital and labor.

This paper contributes new micro-level evidence on how labor taxation affects firm behavior and worker outcomes, exploiting a European Union (EU)-mandated payroll tax reform implemented in 2003 in Norway. Under the reform, firms faced differential tax increases depending on the residential composition of their workforce. Combining this quasi-experimental variation with administrative and survey data, we estimate the causal effects of higher labor costs on a comprehensive set of firm outcomes: employment, innovation, automation, productivity, and the labor share. The results offer direct evidence on how labor taxation shapes firms' decisions and, through them, productivity and the distribution of income between capital and labor.

Payroll taxes are an important source of revenue for financing the Norwegian welfare system: prior to the reform, employees contributed a flat 7.8% of wages nationwide, while employer contributions varied by employee residence, from 0% to 14.1% across five tax zones. This geographically differentiated system, introduced in the 1970s, was intended to reduce regional inequality and prevent depopulation in remote areas.

In 1999, the European Free Trade Association (EFTA) Court ruled that the system violated European Economic Area (EEA) regulations. Norway responded with a 2003 proposal under which payroll tax rates in low-tax zones would gradually rise to match the highest rate by 2007, and implemented the reform from 2004 to 2006, expecting it to be permanent. In July 2006, however, the EFTA Surveillance Authority (ESA) unexpectedly reversed course, ruling that regional differentiation was permissible under the EEA's updated Regional Aid Guidelines (see Section 2). Payroll tax rates accordingly reverted to their pre-reform levels in 2007. Both the 2004 increase and its 2007 reversal were driven by EU-level regulatory decisions unrelated to regional economic conditions within Norway, providing a rare opportunity to study firm responses to arguably exogenous changes in labor costs.

We estimate the causal effects of the reform-induced increase in payroll taxes on firm outcomes, both while the policy was in force (2004–2006) and after its unexpected reversal (2007–2010). Our empirical strategy is a difference-in-differences event study design comparing treated and control firms before and after 2004. In the baseline specification, treatment status is defined by the predicted change in each firm's average payroll tax rate between 2003 (pre-reform) and 2007 (the anticipated year of full harmonization). Firms with a predicted increase of at least three percentage points are classified as treated; the remainder form the control group. Treated firms faced an average predicted increase of 6.1 percentage points, against 0.3 percentage points for controls.[1]

Despite this 5.8 percentage point differential in predicted tax increases, wages evolved similarly across the two groups before and after 2004, implying that the reform raised treated firms' effective cost of labor (wages plus payroll taxes). Employment responded sharply: it fell by 6% at treated firms relative to control firms. Our estimates imply a labor demand elasticity

[1] This dichotomous definition yields a clean comparison between firms facing a substantial tax increase and those facing a negligible one. As a robustness check, we also estimate a continuous specification, which delivers very similar effect sizes.

of (at least) −1, larger in magnitude than the average and median elasticities in the literature (−0.55 and −0.42; Lichter et al., 2015). This substantial employment response also contrasts with the minimum wage literature, which typically finds no or modest employment declines following minimum wage increases (Dube and Lindner, 2024). Importantly, employment did not rebound after the 2007 tax reversal.

Treated firms also became more likely to adopt automation and to expand R&D and process innovation. These responses increased labor productivity, although the increase may partly reflect lower employment, higher capital intensity, and possible changes in workforce composition. Gains in TFP were more modest: A 1-percentage-point increase in the predicted payroll tax rate raised labor productivity (value added per worker) by roughly the same amount and total factor productivity (TFP) by about 0.07%. These gains were accompanied not only by employment but also by a decline in the labor share: for each 1-percentage-point rise in the predicted payroll tax rate, the labor share of value added fell by about 0.8%, alongside a 1% reduction in firm employment. The effects on automation, R&D, innovation, and productivity are more pronounced at large firms than at medium-sized firms, consistent with high fixed costs of automation and innovation (Hubmer and Restrepo, 2021).

To rationalize these findings, we develop a simple model based on Acemoglu and Restrepo's (2019) task-based framework of endogenous automation. Its key feature is that the set of tasks assigned to capital expands endogenously when labor becomes more expensive relative to capital. Payroll taxes then operate through two margins: input substitution and changes in production technology via automation. In the canonical model, only the first margin operates. This endogenous-technology framework quantitatively rationalizes the observed declines in employment and the labor share, along with the rise in labor productivity, while allowing the elasticity of substitution between labor and capital to remain below one.

Given the productivity-displacement trade-off in this framework, a key question is how the increase in payroll taxes affects workers' welfare. To address this, we track incumbent workers—those employed at treated and control firms in 2003. Following the 2004 reform, incumbents at treated firms were no more likely to lose their jobs than those at control firms; the decline in firm employment was driven primarily by reduced hiring rather than increased separations. Yet incumbents saw little wage gain even after the tax reversal, despite persistently higher labor productivity.

Outcomes for workers who are not hired because of the tax shock are not directly observable. Yet even under full reallocation, the modest TFP gains and flat wages at treated firms leave little scope for productivity-driven labor demand gains or for the new-task creation emphasized by Acemoglu and Restrepo (2019) as the "labor reinstatement effect". Taken together, the 2004 reform appears to have sharply and persistently reduced employment and shifted income from labor to capital within affected firms, while only modestly expanding TFP.

By providing rare micro-level evidence on how labor taxation influences firms' choices of production technology—and consequently employment, productivity, and the distribution of income between capital and labor—this paper contributes to four strands of the literature. First, it adds to the work on the determinants of firms' technology adoption and innovation. A central theme in this literature is that labor scarcity—whether overall or for specific groups such as high-skilled or young workers—shapes firms' technology choices, automation strategies, and the direction and intensity of innovation (e.g., Acemoglu, 2010; Beaudry et al., 2010; Acemoglu and Restrepo, 2022). Much of this literature exploits immigration shocks to generate plausibly exogenous shifts in labor scarcity (e.g., Lewis, 2011; Clemens et al., 2018; Lafortune et al., 2019; Gray et al., 2020; Hegna and Ulltveit-Moe, 2021; San, 2023). In contrast, we identify the response to a change in the *price* of labor holding supply conditions constant, allowing us to isolate the substitution toward automation more cleanly.

In related work, Hémous et al. (2025) show that minimum wage hikes affecting downstream firms induce automation innovation among upstream suppliers. We instead study firms directly exposed to a labor cost shock and trace adjustment across a broader set of margins—automation, R&D, innovation, employment, productivity, and the labor share—while also exploiting an unexpected reversal of the shock to document hysteresis. More broadly, we identify payroll taxes as a direct and policy-relevant driver of firms' production-technology choices, thereby contributing to the debate over the taxation of capital versus labor (Acemoglu et al., 2020; Acemoglu and Loebbing, 2025; Beraja and Zorzi, 2025; Kang et al., 2025).[2]

Second, we contribute to the literature on automation, labor demand, and inequality. Recent research emphasizes the displacement-productivity trade-off of automation and distinguishes between technology-induced labor displacement effects and labor reinstatement effects operating through productivity spillovers, the creation of new tasks, and worker reallocation (Acemoglu and Restrepo, 2019, 2022a; Autor et al., 2024; see also Acemoglu and Restrepo, 2020; Autor and Salomons, 2018; Hémous and Olsen, 2022; Moll et al., 2022). Our study examines technology adoption and automation triggered by a labor cost shock, shedding new light on the productivity-displacement trade-off at the firm level: a 1-percentage-point increase in the predicted payroll tax rate raises labor productivity by about 1% and TFP by 0.07%, but reduces employment and the labor share by about 1% and 0.8%, respectively.

Third, we extend the payroll tax literature, which has largely focused on employment and wage effects, as well as how tax incidence depends on the institutional context, adjustment margins, and market power (e.g., Gruber, 1997; Kugler and Kugler, 2009; Saez et al., 2019; Benzarti and Harju, 2021; Lobel, 2024). Specifically, our analysis builds on our earlier paper, Ku et al. (2020), which analyzed the same reform to evaluate whether geographically

[2] A related literature shows that policy-induced reductions in the cost of innovation—through R&D tax credits and other subsidies—affect firms' R&D and innovation outcomes (e.g., Bloom et al., 2002; Zwick and Mahon, 2017; Criscuolo et al., 2019). We instead study how changes in the cost of labor induce R&D and innovation as firms substitute away from labor inputs.

differentiated payroll tax rates achieved their place-based objectives. In this paper, we shift the focus from the regional to the firm level and extend the analysis beyond the reform period to study why employment did not rebound after payroll tax rates returned to their pre-reform levels. We examine a richer set of adjustment margins, including automation, R&D, productivity, and the labor share. This approach helps identify the mechanism behind the large and persistent employment response and connects the Norwegian evidence to the broader debate on how labor taxation shapes technology adoption, productivity, and the distribution of income.

Fourth, we contribute to the literature on hysteresis—the notion that temporary shocks can have lasting effects (Benzarti et al., 2020; Saez et al., 2021; Quach, 2025). In our setting, the effects on employment, labor productivity, and the labor share persist after the payroll tax shock is reversed—as firms likely switched to a more capital-intensive technology—highlighting that short-term policy changes can induce durable shifts in production technology and labor demand.

2. Institutional Setting

2.1 The Payroll Tax Harmonization Reform

Norway's social security system is primarily financed through payroll taxes. During our study period, employees contributed a flat 7.8% contribution of their wages, while employers faced a rate between 0% and 14.1%, depending on their employees' place of residence. Social security benefits are uniform nationwide and do not depend on the employer's contribution rate.

Since the 1970s, the employer payroll tax has been geographically differentiated to reduce regional disparities and limit depopulation in remote and economically disadvantaged areas. Before the 2004 harmonization reform, Norway was divided into five tax zones (see Panel A of Figure A.1). Zone 1, covering the central regions and including the five largest cities, faced a payroll tax rate of 14.1%. Rates were lower in more remote zones, falling to 0% in the northernmost areas (Zone 5). Notably, the applicable tax rate was determined by employees' place of residence, so firms in the same tax zone could face different average payroll tax rates depending on the composition of their workforce.

In 1999, the European Free Trade Association (EFTA) Court ruled that Norway's geographically differentiated payroll tax system was not compliant with European Economic Area (EEA) regulations. After further correspondence, the EFTA Surveillance Authority (ESA) formally demanded changes in 2002. Norway responded in March 2003 by proposing a reform that would gradually phase out the differentiated rates. ESA approved the plan. Beginning in 2004, payroll tax rates in low-tax zones (except Zone 5) were set to rise in steps until they reached the highest rate of 14.1% by 2007. As Panel A of Figure 1 shows, regions in Zone 4, which had a pre-reform rate of 10.6%, experienced an immediate increase to 14.1%. Meanwhile, Zones 2 and 3, with pre-reform rates of 5.1% and 6.4%, were scheduled for stepwise increases starting in 2004 and continuing over the next four years. The northernmost areas (Zone 5) retained its 0% rate, while Zone 1, already at 14.1%, remained unchanged.

Norway implemented the reform between 2004 and 2006 under the presumption that it would be permanent. In July 2006, however, ESA reversed course and reinstated the legality of regionally differentiated payroll taxes, effective January 1, 2007. This unexpected reversal reflected updated Regional Aid Guidelines, which expanded the scope for operating aid in sparsely populated areas. ESA concluded that Norway had sufficiently demonstrated that the scheme was necessary, appropriate, and proportionate, and deemed it compatible with the ESA state aid rules under Article 61(3)(c) and the revised Guidelines. While similar schemes had previously been rejected, the updated rules explicitly permitted regionally differentiated payroll taxes.[3] As a result, tax rates reverted to their pre-reform levels in 2007. The realized trajectory of payroll tax rates is shown in Panel B of Figure 1.

To cushion firms against the sudden tax increases, the government implemented a subsidy scheme. Under the scheme, firms could apply the pre-2004 tax rate to part of their tax bill up to a cap; any remaining payroll was taxed at the higher post-reform rate. ESA approved the scheme on the condition that the annual subsidy did not exceed $\bar{S} = 270{,}000$ NOK (38,136 USD).[4] Accordingly, the subsidy for firm j in year t is given by:

$$S_{j,t} = min\left\{\sum_{i=1}^{N_{j,t}} w_{i,t} \times \left(\tau_{i,t} - \tau_{i,2003}\right), \bar{S}\right\},$$

where $w_{i,t}$ is the total earnings of worker i employed at firm j in year t, $N_{j,t}$ is the number of workers at firm j in year t while $\tau_{i,t}$ and $\tau_{i,2003}$ are the statutory payroll tax rates in the tax zone of the worker in year t (≥ 2004) and in 2003 (the year prior to the reform), respectively. The subsidy scheme largely shielded small firms—those with annual wage bills below 3 million NOK (423,729 USD)—from the tax harmonization. We therefore focus on medium and large firms, for which the tax increases were not fully offset by the subsidy. For these firms, the subsidy reduced average labor costs but was inframarginal for additional payroll beyond the subsidized amount.

In 2003, medium-sized and large firms made up only10% of all firms but accounted for a substantial share of economic activity: 53% of total employment (measured in full-time equivalents), 60% of overall sales revenue, and 94% of total R&D investment. Weighted by employment (to ensure representativeness for employees), the average affected firms had approximately 50 full-time equivalent workers in 2003.

[3] See the ESA news on the reversal of the 2004 reform: https://www.eftasurv.int/newsroom/updates/efta-surveillance-authority-accepts-norwegian-scheme-regionally-differentiated
[4] All monetary amounts in this paper are converted to USD using the average exchange rate for 2003, where 1 USD = 7.08 NOK.

2.2 Concurrent Policies

While firm-specific exposure to the payroll tax shock is plausibly exogenous, our findings should be interpreted within the broader economic and policy environment of the study period (1999–2010). Below, we outline the main policy and macroeconomic developments that occurred alongside the 2004 tax harmonization reform and describe how we account for them in our empirical analysis.

The 2002 R&D Tax Credit. In 2002, the Norwegian government introduced a tax credit to stimulate private-sector R&D investment (see Bøler et al., 2015).[5] Firms could deduct 20% of R&D costs on approved projects, up to a cap of NOK 4 million (USD 560,000). The credit, therefore, affected the marginal cost of R&D primarily for firms with pre-2002 spending below this cap—a group that includes virtually all firms in our sample, treated and control alike. Exposure to the 2002 reform is thus balanced across groups. While the tax credit does not pose a threat to identification, it may have amplified firms' R&D responses to the 2004 payroll tax increase. We discuss possible interactions between payroll tax increases and the R&D tax credit in more detail in Section 5.2.

The Expansion of the European Union in 2004. The EU admitted ten new member states in 2004 (Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, and Slovenia) and two more in 2007 (Bulgaria and Romania). Norway is not an EU member but is a member of the EEA, which provides for the free movement of goods, persons, services, and capital within the single market. Although Norway imposed transitional work-permit requirements on the new accession countries (excluding Cyprus and Malta) until 2009,

[5] Bøler et al. (2015) use the reform to show that lower R&D costs increased imports of intermediate goods, consistent with their model showing that R&D and international sourcing are complementary activities.

immigration from these countries rose sharply—from around 300 arrivals in 2003 to over 16,000 in 2010.[6] In Tables A.4 and A.5, we provide evidence that our main results are unlikely to be driven by increased immigration.

Macroeconomic conditions. Between 1999 and 2010, Norway enjoyed strong macroeconomic conditions, driven largely by rising global oil prices. As a major oil exporter, Norway benefited from the commodity boom: oil prices rose from under $30 per barrel in the early 2000s to a peak of $147 in July 2008. The 2008 global financial crisis briefly disrupted growth and sent oil prices plunging, but the Norwegian economy proved relatively resilient. Firms in oil and gas extraction, along with parts of the oil-related service sector, are subject to separate payroll tax rules that apply the top rate (14.1%) regardless of workers' residence. We therefore exclude these firms from our main sample (see Section 3). In Tables A.4 and A.5, we further show that our results are robust to the exclusion of additional oil-related service sectors, confirming that our findings are not driven by indirect effects of the oil boom.

3. Data and Sample

To study firm-level responses to the reform-induced payroll tax increases, we combine Norwegian administrative records with complementary survey data. We describe the data sources and estimation sample below.

Data. Our analysis combines several administrative and survey datasets from Statistics Norway. The core is a worker-level register covering the universe of employer-employee spells in Norway from 1999 to 2010. It links workers to firms and plants and reports each worker's

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[6] Statistics Norway, *Hvem er arbeidsinnvandrerne fra de nyeste EU-landene?*: https://www.ssb.no/befolkning/innvandrere/artikler/hvem-er-arbeidsinnvandrerne-fra-de-nyeste-eu-landene and StatBank table 07113.

municipality of residence, contracted hours, days worked per year, employment start and end dates, wages, and full-time/part-time status. The register also includes firm identifiers and characteristics such as location and industry. We merge these data with firm balance sheets, which report sales, value added, and fixed (tangible) assets.

We link the matched worker-firm data to Statistics Norway's annual R&D survey, which covers 1999–2010 (except 2000). Firms with at least 50 employees are surveyed every year; firms with 10–49 employees are sampled with probabilities that rise with their prior-year R&D activity. Roughly every two years, the R&D survey is combined with the Community Innovation Survey (CIS), harmonized across EU countries, which asks about process innovation, labor-cost-saving innovation, product innovation, and new-to-the-market products (see Table A.1 for variable definitions and survey questions). We use the 2001, 2006, 2008, and 2010 CIS waves. Because CIS questions refer to innovation over the current and previous two years, we drop the 2004 wave, which straddles the pre- and post-reform periods.

In a final step, we merge these data with external trade statistics reporting Norwegian firms' bilateral imports and exports. The import records cover foreign-manufactured goods entering Norway as well as re-imports of Norwegian goods previously exported for processing, with products classified at the six-digit level of the Harmonized System (HS), the international customs and statistical nomenclature. Following Acemoglu and Restrepo (2022), we use these data to identify imported intermediate inputs associated with the automation of blue-collar industrial jobs. The set of labor-automating intermediates includes dedicated machinery (including robots), numerically controlled machines, regulating instruments, automatic machine tools, welding machines, textile automation, and conveyors.[7] Table A.2 lists all labor-

[7] The categories follow the automation-goods classification of Acemoglu and Restrepo (2022), as operationalized by Domini et al. (2021). We supplement the core automation goods with a small set of industrial capital goods that are not directly labor-replacing but are frequently co-purchased alongside automated machinery (e.g., metal-working presses, woodworking machines, industrial furnaces, and programmable logic controllers). These additions broaden the measure to reflect typical firm-level investment bundles while preserving the structure of Acemoglu and Restrepo's classification.

automating intermediate goods, and Figure A.2 shows the 2003 share of workers employed in firms importing each category. The most prevalent automation imports are regulating instruments, followed by industrial tools and various machine tools.

Sample and Variable Construction. We restrict the sample to employees aged 18 to 65 and exclude employment spells shorter than one month. For our main analysis, we aggregate the matched worker-firm data to the firm level, weighting part-time workers accordingly when constructing firm-level employment.[8] Hourly wages are computed from annual earnings and contracted hours in the employer-employee register.[9] [10]

We keep only private-sector firms with valid municipality information.[11] We exclude firms in the oil and gas extraction and selected related industries that face separate payroll tax rules and pay the highest rate (14.1%) regardless of workers' residence.[12] We also drop firms in industries not covered by the EEA agreement, as these were unaffected by the payroll tax harmonization reform.[13] Next, we restrict the sample to firms operating in 2003, since we use each firm's 2003 workforce composition (the year before the reform) to define treatment status (see Section 4). We also exclude small firms—firms with a wage bill in the pre-reform year 2003 of less than 3 million NOK (423,729 USD)—as they were not directly affected by the

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[8] Statistics Norway records three contract types, each with a listed hours interval. For the two part-time types, we use the lower bound of the interval (4 and 20 hours); for full-time workers, we use the standard 37.5 hours.

[9] Wages are winsorized at the 5th and 95th percentiles. Results are robust to winsorizing at the 1st and 99th percentiles instead.

[10] Results are similar if we instead measure wages using daily earnings, which avoids relying on contracted-hours information.

[11] Our sample includes private-sector firms organized as sole proprietorships, partnerships (general partnership and partnerships with shared liability), private limited companies, and Norwegian-registered branches of foreign enterprises. We exclude all public firms owned by the central government, the Bank of Norway, and state lending institutions.

[12] Firms that pay the full rate include the following (sub) sectors: oil and gas extraction and certain related industries (SN2002 11.10 and 11.20), production and distribution of electricity (SN2002 40.1), building and repairing of ships (SN2002 35.11), mining of non-ferrous metal ores (SN2002 13.2) manufacture of basic iron and steel and of ferroalloys (SN2002 27.1), sectors doing certain financial activities (SN2002 65, 66 and 67), certain transportation sectors (SN2002 60.24) and telecommunication (SN2002 64.20).

[13] This includes firms with activities in agriculture, hunting, forestry and fishing (SN2002 1.1, 1.2, 1.3, 1.4, 1.5, 2.01, 2.02, 5.01, 5.02, 15.1-15.7, 51.2, 51.31, 51.33, 51.381, 61.103 and 63.12).

reform due to the subsidy (see Section 2.1). Finally, we drop firms in the top percentile of the 2003 firm-size distribution (measured by employment) to limit the influence of extremely large firms, since all regressions are weighted by 2003 firm size.

The resulting sample consists of 11,868 firms operating in 2003. For analyses using balance-sheet data, we further exclude firms without mandatory accounting obligations (e.g., sole proprietorships and general partnerships that do not file full annual accounts). This reduces the sample to 11,521 firms. The sample further reduces to 6,329 firms for analyses using the R&D survey and to 5,117 firms for analyses using the innovation (CIS) survey.

4. Empirical Strategy

The payroll tax levied on firms is based on their workers' place of residence. As a result, firms located in the same tax zone may face different average payroll tax rates, depending on where their workforce lives. This is particularly relevant for multi-establishment firms operating across several tax zones and for firms located near zone borders that hire workers residing on both sides.

To measure firm-specific exposure to the tax harmonization reform, we compute each firm's average payroll tax rate in year t using (i) the composition of its workforce (and wage bill) in 2003—the year prior to the reform implementation—and (ii) the statutory payroll tax rate in each worker's tax zone in year t. Holding the firm's worker composition fixed, the average statutory tax rate (hereby "average tax rate") faced by firm j in year t is then given by:

$$\bar{\tau}_{j,t} = \sum_{i=1}^{N_{j,2003}} \omega_i \times \tau_{z(i),t}, \qquad (1)$$

where i denotes a worker employed at the firm in 2003, $\tau_{z(i),t}$ refers to the statutory payroll tax rate in year t for the tax zone in which worker i resided in 2003, and $N_{j,2003}$ is the number of workers employed at firm j in 2003. Each worker-specific payroll tax rate is weighted by the worker's share in the firm's total wage bill in 2003, denoted by ω_i.

Following the tax schedule anticipated as of 2003 (Panel A of Figure 1), we calculate each firm's predicted change in the average payroll tax rate over the originally planned harmonization period from 2003 to 2007:[14]

$$\Delta\tau_j = \bar{\tau}_{j,2007} - \bar{\tau}_{j,2003.} \qquad (2)$$

Figure A.3 shows the distribution of predicted tax changes for firms from 2003 to 2007. While over 30% of firms experienced no change in their predicted tax rates, approximately 17% faced an increase of at least 3 percentage points, and nearly 10% faced an increase of 6 percentage points or more.

Our baseline specification uses a binary treatment indicator. We classify a firm as "treated" if its predicted average payroll tax rates increased by at least three percentage points between 2003 and 2007. Conversely, "control" firms experienced an increase of less than three percentage points. Using equation (2), the treatment indicator for firm j, denoted by T_j, is defined as:

$$T_j = \begin{cases} 1 & if\ \Delta\tau_j \quad \geq 3\ pp, \\ 0 & if\ \Delta\tau_j \quad < 3\ pp. \end{cases} \qquad (3)$$

The 3 percentage-point cutoff ensures that the tax increase was minimal for control firms (averaging 0.3 percentage points) but substantial for treated firms (average 6.1 percentage points; see Table 1). This discrete treatment definition enables a transparent comparison of raw outcome trends between treated and control firms. As a robustness check (Table A.3), we also report results using the continuous measure of predicted tax changes from equation (2).

Panel B of Figure A.1 maps the geographical distribution of treated and control firms. As expected, treatment status is strongly correlated with the statutory tax rate in the firm's tax

[14] The reduced-form results are similar if we instead define exposure using the realized change in firms' average payroll tax rates between 2003 and 2006, the last year before the unexpected reversal.

zone. This relationship is not one-to-one, however, as some firms employ workers who reside outside the firm's tax zone.

Table 1 reports descriptive statistics comparing treated and control firms. Treated firms faced a predicted payroll tax increase of 6.1 percentage points on average, while control firms saw little change (0.28 percentage points). Average hourly wages are lower in treated firms than in control firms, reflecting that low-tax zones prior to the reform were typically more remote and less densely populated. Treated and control firms are similar in size, measured by full-time equivalent employment. Industry composition differs somewhat: treated firms are more likely to operate in manufacturing and are slightly underrepresented in the service sector. In 2003, treated firms were less likely to import automation technologies (23% versus 29%) but more likely to invest in R&D (48% versus 40%). However, conditional on doing R&D, treated firms spent less, both in total and per worker.

We begin our empirical analysis by plotting worker-weighted raw means of different outcomes for treated and control firms, before and after the tax reform, covering the period from 1999 to 2010. For this exercise, we use a balanced sample of firms.[15] To aid comparison, we normalize the treated-control difference to zero in 2003, the year before the reform. We then complement these plots with event study estimates from the following firm-level regression:

$$y_{jt} = \alpha_0 + \sum_{\tau \neq 2003} \beta^{\tau} T_j \times D_{\tau} + \gamma_t + \mu_j + v_{jt}, \qquad (4)$$

where y_{jt} is the outcome of interest, such as (log) number of workers in the firm or the mean (log) hourly wage rate. T_j is an indicator variable for treated firms, and D_{τ} is an indicator equal to 1 in year τ and 0 otherwise. γ_t denotes year fixed effects, and μ_j denotes firm fixed effect

[15] For outcomes based on the R&D or CIS surveys, we do not balance the sample when plotting raw means over time, as we lose too many observations.

(which subsumes the treatment indicator T_j). For outcomes drawn from survey data—such as R&D and innovation—panel coverage is limited, with fewer firms observed repeatedly over time. In these specifications, we therefore replace firm fixed effects with the treatment indicator (T_j), and a set of sector and region fixed effects. This avoids a large loss of observations and consequently improves statistical power.

In this regression, the coefficients β^τ trace the evolution of outcomes in treated relative to control firms before and after the tax reform, with the pre-policy year 2003 as the omitted (reference) year. Under parallel pre-trends, the β^τ estimates for pre-policy years ($\tau < 2003$) should be close to zero—a pattern we confirm empirically. During the reform period (2004–2006), the β^τ coefficients capture the effects of an expected payroll tax increase of about 5.8 percentage points—corresponding to the difference in predicted tax changes between treated and control firms—on firm outcomes. For post-policy years (from 2007 and onwards), the β^τ coefficients capture any persistence of effects after the tax increase was reversed.

As a robustness check, we augment the specification with sector-by-year fixed effects, allowing outcomes to follow different trends across sectors, and thereby addressing differences in industry composition between treated and control firms. We define sectors using 13 sector categories, based on one- to two-digit NACE codes.[16] Moreover, firm fixed effects ensure that the estimated post-reform differences are not driven by changes in the composition of treated and control firms over time. In practice, adding sector-specific time trends and firm fixed effects has little impact on our estimates.

We additionally estimate the following difference-in-differences (DID) equation at the firm level:

$$y_{jt} = \mu_j + \delta_t + \beta T_j \times I(t \geq 2004) + \epsilon_{jt}, \quad (5)$$

[16] Our results are overall robust to instead using two-digit NACE code to construct sector-specific time trends.

where μ_j denotes firm fixed effects (which subsume the treatment indicator T_j), and δ_t denotes year fixed effects. The variable $I(t \geq 2004)$ equals 1 for post-reform years $(t \geq 2004)$ and 0 otherwise. For outcomes based on survey data—such as R&D and innovation—we replace firm fixed effects with the treatment indicator (T_j) and additionally include sector and region fixed effects. Because survey coverage is limited and firms are often observed only intermittently, imposing firm fixed effects would substantially reduce the effective sample size and lower statistical power.

The parameter of interest, β, captures the combined contemporaneous and persistent effects of a payroll tax increase of approximately 5.8 percentage points. The estimates remain largely unchanged if we additionally include sector-by-year fixed effects in the regression.

Throughout the empirical analysis, we weight firms by their 2003 employment (measured in full-time equivalents). Standard errors are clustered at the commuting zone level.[17]

5. Firm Responses to Rising Labor Costs

5.1 Firm Wages and Employment

Wages. Whether an exogenous payroll tax increase translates into higher labor costs depends on the incidence of the tax. If firms can fully pass the burden onto workers through lower wages, payroll tax increases leave labor costs unchanged. We therefore begin by examining how the reform affected average hourly wages in the firm.

Panel A of Figure 2 plots average log hourly wages for treated and control firms over time, normalized to zero in 2003. Before the reform, the two groups exhibited parallel wage

[17] There are 46 commuting zones; see Bhuller (2009) for a documentation of the construction of commuting zones in Norway. Our findings are overall robust to instead cluster at the firm or at the municipality level (428 municipalities).

growth. After the reform, we find little evidence of a relative wage decline at treated firms, suggesting limited pass-through of the payroll tax increase to workers' wages. If anything, wages at treated firms began to rise relative to controls after 2007. Panel B, which plots event-study coefficients from equation (4), confirms this pattern.

Panel A of Table 2 reports the corresponding difference-in-differences (DID) estimates from equation (5). The estimated effects are close to zero in both the full sample (1999–2010, column (1)) and the sample restricted to the reform period (1999–2006, column (2)). Column (3) excludes the years the reform was in force (2004–2006) to isolate the longer-run wage response, resulting in a small and statistically insignificant positive effect. Column (4) presents results from a first-difference specification comparing 2003–2006 wage changes in treated and control firms, which likewise indicates minimal wage adjustments.

Employment. We present the corresponding employment analysis in Panels C and D of Figure 2. Treated and control firms followed similar employment trends before the reform. Immediately after 2004, however, employment at treated firms dropped sharply relative to control firms, and the effect is sizable: by 2006—three years after the tax increase—employment at treated firms had declined by about 6%.

In a canonical model with fixed production technology (e.g., Acemoglu and Autor, 2011), higher labor costs reduce labor demand, but employment should recover once the tax increase is reversed. This is not what we observe: the employment gap between treated and control firms shows no sign of narrowing after 2007, when payroll tax rates reverted to pre-reform levels.

The corresponding DID estimates in Panel B of Table 2 confirm this pattern. The point estimates imply an employment decline of roughly 6% in response to a payroll tax increase of about 6 percentage points—regardless of whether we consider the full period (column (1)), the period during which the tax increase was in place (column (2)), or the period after the tax increase was reversed (column (3)). A first-difference specification that compares 2003–2006 employment changes in treated and control firms yields a similar decline (column (4)).

Robustness. The wage results in Panels A and B of Figure 2 and Panel A of Table 2 may conflate tax-induced changes in individual wage rates with tax-induced shifts in workforce composition. If treated firms disproportionately reduce employment among low-wage workers, for instance, average wages in the firm could rise even when individual wages do not. To address this concern, columns (1) to (3) in Panel C of Table 2 report worker-level estimates of equation (5) with worker fixed effects, which track wage changes within individuals. This specification isolates composition-constant wage changes within the firm, assuming that worker sorting into firms is based on time-invariant characteristics. Accounting for changes in the workforce composition yields slightly more negative wage effects (−0.008 to −0.010), suggesting a modest improvement of workforce quality at treated firms. The estimates remain statistically insignificant, however, and are far smaller than the −0.058 implied by full pass-through. Restricting the sample to workers employed at the same firm in both 2003 and 2006 (“stayers”) and comparing their wage growth across treated and control firms in column (4) once again yields a minimal wage response. Overall, these findings reinforce our conclusion that the payroll tax increase substantially raised firms’ labor costs.

Our analysis so far has focused on the binary treatment indicator defined in equation (3). In Panel A of Table A.3, we report wage and employment effects using the continuous measure of exposure to the tax reform, replacing the binary treatment indicator T_j in equation (5) with its continuous counterpart as specified in equation (2). The estimates in columns (1) and (2) again show little evidence that firms shifted the tax burden onto workers. At the same time, the point estimate in column (3) indicates that a 1 percentage-point increase in the predicted payroll tax rate reduces employment by 0.9%, close to the magnitude in our baseline specification.[18]

Table A.4 reports robustness checks based on variants of equation (5). For comparison, column (1) reproduces the baseline estimates from Table 2 (Panels A and B, column (1)). Column (2) allows time effects to vary by sector. Column (3) addresses the concern that treated and control firms may have experienced different immigrant inflows following the 2004 EU enlargement by interacting the 2003 EU8 immigrant share in the firm's commuting zone with year fixed effects, thereby flexibly controlling for projected immigrant inflows into local labor markets (see Card, 2001). Although the baseline sample already excludes firms in oil and gas extraction and certain related service industries (Section 3), column (4) further excludes oil-linked service sectors to ensure that the results are not driven by oil activity or indirect effects of the oil boom.[19] Across all specifications, the wage response remains small and statistically indistinguishable from zero (Panel A), while employment falls substantially by around 6% (Panel B).

Backing Out the Labor Demand Elasticity. In summary, we find little evidence that firms shifted the payroll tax increase onto workers through lower wages. Treated firms, therefore, faced higher labor costs after the harmonization reform and responded by cutting employment. To back out the firm's labor demand elasticity, we need to scale the employment response to the tax reform by the implied increase in the firm's labor costs. The capped subsidy complicates the mapping from statutory tax-rate changes to labor costs: payroll

[18] The point estimate in column (1) of Panel B, Table 2 indicates that a 5.8 percentage point increase in the predicted payroll tax rate reduced firm employment by 6%, corresponding to an approximate decline of about 1% in employment for a one percentage point increase in the tax rate.

[19] Specifically, we use the classification of oil extraction and related service sectors from Statistics Norway (https://www.ssb.no/246994/naeringsundergrupper-i-standard-for-naeringsgruppering-sn2007-som-er-gruppert-som-petroleumsrettet-leverandorindustri-og-utvinningstjenester). Using this classification, we additionally exclude 603 firms with two-digit SN2002 codes 28, 29, 31, 35, and 36.

covered by the subsidy continued to face the pre-reform rate, while payroll above the cap faced the higher post-reform rate (see Section 2.1). Our preferred scaling is in terms of the predicted change in the firm's payroll tax rate (i.e., 0.058) net of any wage adjustments (which, in our contexts, are negligible). Since we exclude small firms that were largely shielded by the subsidy, the subsidy is inframarginal for expansions for the firms in our sample. The predicted statutory tax increase is therefore a reasonable proxy for the marginal labor-cost shock relevant for firms' labor demand. This scaling yields an implied labor demand elasticity of about -1 (-0.06/0.058, assuming no wage adjustments).

This elasticity is more negative than typical estimates in the literature. [20] Lichter et al. (2015), in a meta-analysis, report a mean of −0.551 and a median of −0.420. Studies that infer the elasticity from minimum wage increases generally find smaller magnitudes, with many estimates being positive: Dube and Lindner (2024) report a median of 0.02 for the overall workforce and broad subgroups, and −0.17 for narrow subgroups such as teens and restaurant workers. In Section 6, we interpret the large implied labor demand elasticity through the lens of the endogenous-technology framework of Acemoglu and Restrepo (2019).

Margins of Employment Adjustments. In Figure 3, we examine how treated firms adjust employment. Panel A decomposes the tax-induced employment decline between 2003 and 2006 (−7%, from column (3) in Panel B of Table 2) into within-plant adjustments (the intensive margin) and an extensive-margin component driven by plant entry and exit.[21] About 60% of the decline is attributable to within-plant adjustments, with the remaining 40% due to changes in plant entry and exit. Panel B further breaks down the extensive-margin

[20] The large implied elasticity is not an artifact of scaling the employment response by the predicted statutory tax increase. Scaling instead by the subsidy-adjusted increase in average labor costs would imply an even larger elasticity in absolute value.
[21] Because our regressions include firm fixed effects, the employment effect in Panel B of Table 2 does not capture changes operating through firm entry or exit. Firms—especially multi-plant firms—may nonetheless respond to higher labor costs by closing plants or foregoing new ones.

component and shows that the net decline is driven primarily by a reduced likelihood of opening new plants at treated firms, not by increased closures. Panel C shows that the within-plant decline is entirely due to reduced hiring; if anything, separations decline slightly at treated firms relative to controls.

These results suggest that incumbent workers—those employed in 2003, just before the reform—did not face a higher layoff risk, whether in continuing plants or through plant closures. Treated firms instead adjusted primarily by hiring less in existing plants and by refraining from opening new ones. We examine the effects on incumbent workers in more detail in Section 6.2.

5.2 Automation, R&D Investments, and Innovation

Treated firms may have responded to higher labor costs by adopting labor-saving technologies and altering their production processes. Such adjustments could help explain not only the sizable employment decline and the unusually large implied labor demand elasticity, but also the absence of an employment rebound after the unexpected 2007 reversal of the tax increase. To test this hypothesis, we examine the reform's effects on firms' imports of automation technologies, R&D investment, and innovation outcomes.

Automation. Panel A of Figure 4 plots the share of treated and control firms importing automation technologies over time, with 2003 means normalized to zero for comparability. Panel B reports the corresponding event-study estimates from equation (4). Despite wide confidence intervals, the figures suggest that treated firms responded to the tax increase with an immediate rise in their propensity to import automation technologies relative to control firms during the reform period (2003–2006).

Column (1) of Table 3 reports the corresponding DID estimate from equation (5) for the full sample period (1999–2010). The point estimate implies that a 6 percentage-point increase in the payroll tax rate raises the probability of importing automation technologies by about 2 percentage points—roughly 10% of the pre-reform rate of 0.23 among treated firms. By contrast, the firm's overall import share is largely unaffected (column 2).

R&D Investments and Innovation. Next, we examine whether higher labor costs affected R&D investments, using the annual R&D survey. Figure 5 provides suggestive evidence that, relative to control firms, treated firms tended to increase their R&D investments (conditional on non-zero investments; Panels C and D) and employed more R&D workers (Panels E and F) after the payroll tax increase. At the same time, the share of firms with any R&D investments (Panels A and B) appears to have declined after the reform.

The DID estimates in columns (3)-(6) of Table 3, covering the years 1999 to 2010, support this pattern. Specifically, a 6-percentage-point increase in the payroll tax rate is associated with a 14% decline in the share of firms investing in R&D (the coefficient of −0.071 in column (3) divided by the treatment group mean, 0.475). Conversely, conditional on investing in R&D, expenditure rises by approximately 23% (column (4)). Column (5) incorporates both extensive and intensive margins by including firms that do not invest in R&D and estimating a Poisson Pseudo-Maximum Likelihood (PPML) model, as proposed by Silva and Tenreyro (2006). The estimated effect is 21% ($\exp(0.187) - 1$), which is similar in magnitude to the estimate in column (4). This suggests that the increase in R&D intensity among investing firms more than offsets the decline in R&D participation. Finally, column (6) shows that the number of R&D workers (full-time equivalents) increases by 22% following the tax increase.

The sizable increase in R&D spending at the intensive margin should be interpreted in light of the R&D tax credit introduced in 2002, which lowered the effective cost of R&D (see Bøler et al., 2015). As discussed in Section 2.2, treated and control firms were similarly exposed to this policy change, so it is unlikely to threaten the identification of the impacts of the 2004 payroll tax reform. At the same time, the presence of a generous tax credit may have amplified the firms' R&D responses to the 2004 payroll tax increase. Evidence in Figure A.4 supports this interpretation. Before 2002, treated firms spent less on R&D than control firms (Panel A). In 2002 and 2003, after the R&D tax credit was introduced but before the payroll tax reform, treated and control firms claimed tax credits at similar rates (Panel C). After the 2004 payroll tax increase—and not earlier—treated firms increased their R&D spending (conditional on doing R&D), gradually converging toward the levels of control firms (Panels A and B). In 2004, treated firms also became somewhat more likely to claim the tax credit than control firms (Panels C and D). Together, these dynamics suggest that treated firms responded to the payroll tax hike by increasing R&D investment, partly facilitated by the newly introduced tax credit.

Building on the R&D results, we investigate whether treated firms report more innovations due to higher R&D investment, using data from the CIS. Table 4 points in this direction, though the estimates are imprecise and should be interpreted cautiously. Column (1) shows a marginally significant rise in process innovation of 7.6 percentage points—about 20% relative to the 2001 mean of 0.39—in response to the 6-percentage-point payroll tax increase. Column (2) indicates a similar positive effect on labor cost-saving innovation. In contrast, we find little evidence that the payroll tax hike led to increases in product innovation or new-to-the-market innovations (columns (3) and (4)).

In sum, the results suggest that firms responded to the payroll tax increase not only by importing more automation goods but also by stepping up R&D and pursuing innovations aimed at reducing labor costs. These findings are broadly robust to using a continuous treatment measure (see Table A.3), adding sector-by-year fixed effects or controls for regional immigration employment shares, and excluding additional oil-related industries (see Table A.5). Overall, the evidence supports the view that firms altered their production methods in response to the tax increase, shifting toward more capital-intensive production.

5.3 Firm Performance, Productivity, and the Labor Share

Next, we examine how the payroll tax increase affected firms' performance, focusing on sales, capital intensity, labor productivity, TFP, and the labor share. As we discuss in Section 6.1, higher labor costs can affect these outcomes even without changes in production technology. Technology responses—such as automation and labor-saving innovations—may, however, amplify (or, in some cases, mitigate) these effects.

Sales and Capital Investments. Despite the large reduction in employment, there is little evidence that the payroll tax reduced firms' sales or their capital stock (Panels A to D of Figure 6 and columns (1) and (2) in Panel A, Table 5). Furthermore, the results in Panels E and F of Figure 6 and column (3) of Table 5 show that the payroll tax increase of about 6 percentage points significantly boosted capital investment per worker by nearly 14%. This effect persisted even after the payroll tax rate returned to its pre-reform level.

Productivity and the Labor Share. We next examine the effects of the payroll tax increase on labor productivity, total factor productivity (TFP), and the labor share.[22] Panels A and B of Figure 7 show that labor productivity (value added per worker) rose significantly at treated

[22] TFP is estimated using the Olley and Pakes (1996) control function method, which uses investment to proxy for unobserved productivity shocks. Results are robust to the Levinsohn and Petrin (2003) method, which uses intermediate input demand as the proxy.

firms relative to controls throughout the post-reform period, while the two groups followed similar trends before the reform. The DID estimate in column (4) of Table 5 implies a 6.2% increase in labor productivity in response to the roughly 6-percentage-point payroll tax rise.

The increase in labor productivity is perhaps unsurprising given the sharp decline in employment and the rise in capital investment per worker. Panels C and D of Figure 7, however, show that TFP—output net of measured inputs—also moderately increased in treated firms relative to controls after the reform. The DID estimate in column (5) of Table 5 implies that the roughly 6-percentage-point payroll tax increase raised TFP by about 0.4%. The effect points to improved production efficiency—higher output for a given level of inputs—and persists after payroll tax rates returned to their pre-reform levels. While this TFP gain is difficult to reconcile with the canonical fixed-technology model, it aligns with the rise in automation imports, R&D spending, and labor-saving innovation documented in Section 5.2.

Panels E and F of Figure 7 show that the labor share—the proportion of value-added accruing to labor, including payroll taxes—fell at treated firms relative to controls after the tax increase, with little sign of rebound once rates return to pre-reform levels. The DID estimate in column (6) of Table 5 implies that the 6 percentage-point payroll tax increase reduced the labor share by about 5%. This result highlights the reform's distributional implications: the payroll tax increase, alongside rising automation, R&D, and labor-saving innovation, shifts value added from labor to capital within affected firms.

Large vs. Medium-Sized Firms. So far, we have pooled all medium- and large-sized firms affected by the 2004 reform (Section 2.1). We now split the sample at the median 2003 wage bill (NOK 5,328,000; USD 752,500), defining firms above the median as large and those below as medium-sized. In both subsamples, treated firms faced a similar increase in the predicted payroll tax rate—about 6 percentage points—relative to their respective controls (Table A.7).

Panel A of Table 6 reports wage and employment results separately for large and medium-sized firms. Columns (1) and (4) show little evidence of wage adjustment in either group, implying that neither was able to shift the tax burden onto workers. Labor costs (wages plus payroll taxes) therefore rose by similar amounts in the two groups. Employment declined in both medium-sized and large firms, with the decline being larger in large firms (though this difference is not statistically significant).

Clear differences emerge for automation and innovation outcomes. Only large firms raise automation imports, R&D spending, and labor-saving process innovations after the payroll tax increase; medium-sized firms, by contrast, significantly reduce R&D (Panel B of Table 6). This pattern is consistent with models in which financially constrained or mid-productivity firms cut R&D—an internally financed and easily adjustable expense—in response to adverse cost shocks. It may also reflect the substantial fixed costs of automation and innovation, which make these investments less attractive for medium-sized firms despite rising labor costs, while large firms operate at a scale where such investments pay off (see, e.g., Hubmer and Restrepo, 2021).

Mirroring these differences, TFP rises only at large firms, and the increase in labor productivity and decline in the labor share are somewhat more pronounced at large firms than at medium-sized ones (Panel C of Table 6).

Overall, these findings support the view that technology responses at large firms—higher automation, R&D, and labor-saving innovation—contribute to the TFP gains and amplify the effects of the payroll tax increase on labor productivity and the labor share. In contrast, medium-sized treated firms instead adjusted primarily through employment reductions, with little evidence of technological upgrading.

Recap. We find that higher labor costs—driven by the payroll tax increase—lead large firms to import more automation goods, raise R&D spending, and adopt labor-saving innovations. These adjustments point to a shift toward more capital-intensive production that raises labor productivity and TFP but amplifies employment losses and reduces the labor share.

Next, we develop a simple theoretical framework contrasting the effects of labor cost shocks under endogenous versus fixed technology. The model separates the direct effects of higher labor costs—holding the production function fixed, as in the canonical benchmark—from the additional effects arising when firms automate tasks and adopt new production methods.

6. Theoretical Framework

6.1 A Simple Model of Endogenous Automation

The set-up. Consider a simplified version of the static task-based framework proposed by Acemoglu and Restrepo (2018, 2019) and Acemoglu et al. (2020). In this model, there is a representative firm that produces a final good by combining the services of a continuum of tasks indexed by $x \in [0,1]$. The production function aggregates these tasks using a constant elasticity of substitution (CES) function, with elasticity of substitution between tasks denoted by $\delta \in (0, \infty)$. Then, the final output Y is given by:

$$Y = \left(\int_0^1 y(x)^{\frac{\delta-1}{\delta}} dx \right)^{\frac{\delta}{\delta-1}}$$

Each task is produced using either capital or labor, so that:

$$y(x) = k(x) + \psi(x) l(x),$$

where $k(x)$ is the capital input used in the production of task x, $l(x)$ is the labor input employed in task x, and $\psi(x)$ represents the productivity of labor relative to capital in task x.

The function $\psi(x)$ is positive, continuous, differentiable, and strictly increasing in x, implying that labor has a comparative advantage in tasks with higher indices.

Let $L = \int_0^1 l(x)dx$ and $K = \int_0^1 k(x)dx$ denote the aggregate quantities of labor and capital, respectively. The firm's total cost is then given by $w(1+\tau)L + rK$, where w is the wage rate, τ is the payroll tax rate faced by firms and r is the rental rate of capital. We assume that markets for capital, labor, and the final good are perfectly competitive.

Since capital and labor are perfect substitutes in the production of each task, there exists a unique cutoff θ such that tasks in $[0, \theta]$ will be produced with capital and tasks in $(\theta, 1]$ will be produced with labor. We can think of θ as the level of automation. Following Acemoglu and Restrepo (2018), the aggregate production can then be written as:

$$Y = \left[\theta^{\frac{1}{\delta}} K^{\frac{\delta-1}{\delta}} + \left(\int_\theta^1 \psi(x)^{\delta-1} dx\right)^{\frac{1}{\delta}} L^{\frac{\delta-1}{\delta}}\right]^{\frac{\delta}{\delta-1}} \quad (6)$$

Aggregate output therefore closely resembles a standard CES production function where δ is the elasticity of substitution between capital and labor. In contrast to the canonical model, the input share θ (or the level of automation) is not exogenous but a firm's choice variable.

Firms choose labor, capital, and θ to maximize profits. We assume that capital supply is partially elastic. Let γ denote the capital supply elasticity ($\gamma = dlogK^s/dlogr$). We are agnostic about labor supply and the determination of the wage rate w in equilibrium. Instead, we derive comparative statics with respect to the (log) of the marginal cost of labor faced by firms, $logc_L = log\ w(1+\tau)$, which the firm takes as given. In our setting, the increase in the payroll tax rate τ barely changes the wage rate (see Panel A in Table 2). Hence, the payroll tax increase raises the costs of labor faced by affected firms.

Below, we present a series of comparative statics to contrast the predictions of the endogenous technology framework (Acemoglu and Restrepo, 2019) with those of the canonical model featuring fixed production technology (Acemoglu and Autor, 2011). Formal proofs are provided in Appendix B.

Labor costs and automation. In Appendix B.1, we show that an exogenous increase in the marginal costs of labor leads to higher levels of automation:

$$\frac{d\theta}{d\log w(1+\tau)} = \frac{\psi(\theta)}{s^K\psi'(\theta)} > 0 \quad (7)$$

where $s^K = \frac{rK}{w(1+\tau)+rK}$ denotes the capital cost share. Therefore, when confronted with higher labor costs, some tasks previously performed by labor are now carried out by capital. Thus, according to the model, the observed behavior—that higher payroll tax rates lead firms to increase their investments in R&D, import more automation goods, and pursue labor-saving innovations—can be understood as a shift toward a more capital-intensive production process.

Labor costs and the demand for labor. We show that an increase in the marginal costs of labor affects labor demand in two ways: directly, holding the production function constant, and indirectly, through automation (see Appendix B.2):

$$\frac{d\log L}{d\log w(1+\tau)} = -\underbrace{\frac{\delta+(1-s^K)\gamma}{s^K}}_{\substack{\text{labor demand}\\ \text{elasticity in the canonical}\\ \text{model}}} - \underbrace{\frac{1}{s^K}\frac{\psi(\theta)^{\delta-1}}{\int_{\theta^*}^{1}\psi(x)^{\delta-1}dx}\frac{d\theta}{d\log w(1+\tau)}}_{\substack{\text{labor}-\text{reducing effect due to}\\ \text{automation}}} \quad (8)$$

Here, $-\frac{\delta+(1-s^K)\gamma}{s^K}$ corresponds to the labor demand elasticity in the canonical model with a CES production function (where δ denotes the elasticity of substitution between capital and labor, s^K the capital cost share, and γ the capital supply elasticity).

Our wage and employment estimates imply a large labor demand elasticity of approximately -1, an estimate that is substantially higher than typical values reported in the literature. The task-based model can explain the large implied elasticity: in this setting, higher labor costs not only reduce labor demand directly but also trigger automation, thereby amplifying employment losses. The shift toward more capital-intensive production also helps explain why employment remained depressed even after the payroll tax increase was reversed in 2007.

Labor costs and labor productivity. As with labor demand, an increase in the marginal cost of labor will increase labor productivity directly (holding the production function constant) and indirectly through automation (see Appendix B.3):

$$\frac{d\log\frac{Y}{L}}{d\log w(1+\tau)} = \underbrace{\delta}_{\substack{\text{productivity}\\ \text{enhancing effect in}\\ \text{the canonical model}}} + \underbrace{\frac{\psi(\theta)^{\delta-1}}{\int_{\theta^*}^{1}\psi(x)^{\delta-1}dx}\frac{d\theta}{d\log w(1+\tau)}}_{\substack{\text{productivity enhancing effect due to}\\ \text{automation}}} \quad (9)$$

In the absence of automation, the elasticity of substitution between capital and labor determines the effect of labor costs on labor productivity growth. Using the predicted payroll tax increase as a proxy for the increase in marginal labor costs, our estimates in column (4) of Table 5 imply a 1.1% increase in labor productivity for every 1% increase in marginal labor costs, assuming wages do not adjust to the payroll tax hike (calculated as 0.062 / 0.058).

In the canonical model, gains in labor productivity of this magnitude can only be reconciled with an elasticity of substitution between capital and labor of around 1. While this value lies within the range reported in the literature, estimates below 1 are more common. For example, a meta-analysis of 77 studies by Knoblach et al. (2020) reports plausible values between 0.45 and 0.87, while Gechert et al. (2022) estimate values in the range 0.3–0.5.

By contrast, the task-based model aligns with the observed increase in labor productivity even when the elasticity of substitution between capital and labor is well below one. Higher labor costs encourage automation and raise output per worker, an adjustment mechanism that is absent under fixed technology. Unlike the canonical model, the task-based model can also account for the observed increase in the firm's TFP following the tax increase.

Labor costs and the labor share. The effect of an increase in the marginal cost of labor on the labor share s^L can be expressed as (see Appendix B.4):

$$\frac{d\log s^L}{d\log w(1+\tau)} = \underbrace{(1-\delta)}_{\substack{\text{labor share effect}\\ \text{in the canonical}\\ \text{model}}} - \underbrace{\frac{\psi(\theta)^{\delta-1}}{\int_{\theta^*}^{1}\psi(x)^{\delta-1}dx}\frac{d\theta}{d\log w(1+\tau)}}_{\substack{\text{labor share effect due to}\\ \text{automation}}} \quad (10)$$

This expression highlights that the labor share responds to rising labor costs even in the absence of automation. The sign of the effect depends on the elasticity of substitution between capital and labor. When this elasticity is below 1—as much of the literature suggests—the canonical model predicts an increase in the labor share following a rise in labor costs.

However, we find that the labor share declined in treated firms relative to control firms after the payroll tax increase (see column (6) of Table 5). This pattern is difficult to reconcile with the canonical model but arises in the version with endogenous automation: higher payroll taxes induce firms to automate, thereby reducing the share of income paid to labor.

6.2 Discussion

The model highlights an important trade-off between productivity, employment, and the labor share associated with automation. Our empirical analysis quantifies this trade-off at the firm level: A 1-percentage-point increase in the predicted payroll tax rate raises labor productivity by about 1% and total factor productivity by about 0.07%, but lowers firm employment and the labor share by about 1 and 0.8%, respectively.

The welfare implications of this trade-off depend critically on what happens to the workers who would have been employed in automating firms had automation not occurred. To shed light on this, we track individuals who were employed at treated and control firms in 2003, before the tax increase. Table 7 compares labor market outcomes for these incumbents during the reform period (2004–2006; Panel A) and after the payroll tax was reversed (2007–2010; Panel B). Column (1) shows no significant difference in the probability of being in employment between treated and control firms. Incumbent workers, therefore, did not face an increased layoff risk after the tax increase, despite the sharp decline in firm employment.[23] This is consistent with Figure 3, which shows that treated firms adjusted employment primarily by reducing hiring, rather than by increasing separations.

Next, we examine whether incumbent workers benefited from automation-driven productivity gains through higher wages. Perhaps unsurprisingly, incumbent workers experience similar wage growth in treated firms during the reform period (Panel A of Table 7)—regardless of whether we consider all incumbents (assigning zero wages to the non-employed, column (2)), only those employed (column (3)), or firm stayers (column (4)). More interestingly, we also find no positive wage effects for firm stayers in the post-reversal period (2007-2010; Panel B, column (4)), despite the strong increase in labor productivity in treated firms.

The welfare implications of the payroll tax increase for incumbent workers are therefore mixed. While they were largely insulated from employment reductions driven by rising labor costs and automation, they benefited little from the resulting increase in labor productivity in the form of higher wages. Instead, increased labor costs and automation appear to have shifted income away from labor and toward capital within affected firms.

Additionally, the overall welfare effects of the reform hinge on how the careers of workers who are not hired because of the tax shock are affected—a dimension that is not

[23] In fact, incumbent workers are more likely to remain employed with their firms over a longer horizon during the 2004-2007 period (see column (1) in Panel B). A possible explanation for this finding is that reduced hiring in other firms following the tax increase may have limited workers' mobility, effectively trapping them in their existing firms. Cornelissen et al. (2025) provide empirical evidence on this channel in the context of a business tax reform.

directly observable. More broadly, the welfare implications of the payroll-tax-induced increase in automation depend on whether displaced or non-hired workers are reallocated to productive employment elsewhere, and on whether automation generates offsetting productivity spillovers or new labor-intensive tasks—the "labor reinstatement channel" emphasized by Acemoglu and Restrepo (2019). While our empirical design does not allow us to directly examine these channels, the direct gains in total factor productivity from automation—0.07% for a 1-percentage-point increase in the predicted payroll tax rate—seem too modest to generate offsetting effects at scale.

7. Conclusions

This paper exploits an EU-mandated payroll tax reform in Norway to estimate the causal effects of higher labor costs on firms. Treated firms faced a differential payroll tax increase of about 6 percentage points between 2004 and 2006, driven by EU-level regulatory decisions unrelated to local economic conditions, and the increase was unexpectedly reversed in 2007. Wages evolved similarly at treated and control firms, implying that the reform raised the effective cost of labor. We provide evidence that this increase in labor costs prompted treated firms to switch to a more capital-intensive production process: They were more likely to adopt automation and to expand R&D and labor-cost reducing process innovation. This technology adoption yielded productivity gains: a 1-percentage-point increase in the predicted payroll tax rate raised labor productivity by roughly 1% and TFP by about 0.07%. However, it also came at a cost: for each 1-percentage-point rise in the predicted payroll tax rate, the labor share fell by about 0.8% and employment declined by about 1%.

We rationalize these patterns with a model of endogenous automation based on Acemoglu and Restrepo (2019), in which payroll taxes operate through both input substitution and shifts in production technology. The framework accounts for the large and persistent declines in employment and the labor share, as well as the rise in labor and total factor productivity, without requiring an elasticity of substitution above one.

The welfare implications are mixed. Incumbent workers at treated firms did not face a higher risk of non-employment than those at control firms, since adjustment primarily occurred through reduced hiring rather than increased separations. However, incumbents experienced minimal wage gains even after the tax reversal, despite sustained increases in labor productivity within treated firms. Overall, the reform led to a sharp reduction in employment and a shift in income from labor to capital in affected firms, while increasing TFP only modestly.

By identifying payroll taxes as a direct and policy-relevant driver of firms' production-technology choices—and by providing new insights on the productivity-displacement trade-off associated with automation—we speak to the ongoing debate over the taxation of capital versus labor (Acemoglu et al., 2020; Acemoglu and Loebbing, 2025; Beraja and Zorzi, 2025; Kang et al., 2025). Payroll taxes, while essential for financing social insurance, can unintentionally accelerate automation by raising the relative cost of labor. The resulting productivity gains come at the expense of reduced employment and a lower labor share. The persistence of these effects underscores the importance of accounting for hysteresis in tax policy design: temporary interventions can induce durable shifts in firms' production technologies, with lasting consequences for employment and income distribution.

References

Acemoglu, Daron. “When does labor scarcity encourage innovation?.” *Journal of Political Economy* 118, no. 6 (2010): 1037-1078.

Acemoglu, Daron, and David Autor. “Skills, tasks and technologies: Implications for employment and earnings.” In *Handbook of Labor Economics*, vol. 4, pp. 1043-1171. Elsevier, 2011.

Acemoglu, Daron, and Jonas Loebbing. “Automation and polarization.” *Journal of Political Economy*, forthcoming (2025).

Acemoglu, Daron, Andrea Manera, and Pascual Restrepo. “Does the US tax code favor automation?.” *Brookings Papers on Economic Activity*, no. 1 (2020): 231-300.

Acemoglu, Daron, and Pascual Restrepo. “Modeling automation.” *AEA papers and proceedings*, vol. 108 (2018): 48-53

Acemoglu, Daron, and Pascual Restrepo. “Automation and new tasks: How technology displaces and reinstates labor.” *Journal of Economic Perspectives* 33, no. 2 (2019): 3-30.

Acemoglu, Daron, and Pascual Restrepo. “Robots and jobs: Evidence from US labor markets.” *Journal of Political Economy* 128, no. 6 (2020): 2188-2244.

Acemoglu, Daron, and Pascual Restrepo. “Demographics and automation.” *Review of Economic Studies* 89, no. 1 (2022): 1-44.

Autor, David, and Anna Salomons. “Is automation labor share-displacing? Productivity growth, employment, and the labor share.” *Brookings Papers on Economic Activity* (2018).

Autor, David, Caroline Chin, Anna Salomons, and Bryan Seegmiller. “New frontiers: The origins and content of new work, 1940–2018.” *Quarterly Journal of Economics* 139, no. 3 (2024): 1399-1465.

Beaudry, Paul, Mark Doms, and Ethan Lewis. "Should the personal computer be considered a technological revolution? Evidence from US metropolitan areas." *Journal of Political Economy* 118, no. 5 (2010): 988-1036.

Benzarti, Youssef, Dorian Carloni, Jarkko Harju, and Tuomas Kosonen. "What goes up may not come down: asymmetric incidence of value-added taxes." *Journal of Political Economy* 128, no. 12 (2020): 4438-4474.

Benzarti, Youssef, and Jarkko Harju. "Using payroll tax variation to unpack the black box of firm-level production." *Journal of the European Economic Association* 19, no. 5 (2021): 2737-2764.

Beraja, Martin, and Nathan Zorzi. "Inefficient automation." *Review of Economic Studies* 92, no. 1 (2025): 69-96.

Bhuller, Manudeep S. Inndeling av Norge i arbeidsmarketsregioner [The division of Norway into labor market regions]. *Statistics Norway mimeo*, 2009/24.

Bloom, Nick, Rachel Griffith, and John Van Reenen. "Do R&D tax credits work? Evidence from a panel of countries 1979–1997." *Journal of Public Economics* 85, no. 1 (2002): 1-31.

Bøler, Esther Ann, Andreas Moxnes, and Karen Helene Ulltveit-Moe. "R&D, international sourcing, and the joint impact on firm performance." *American Economic Review* 105, no. 12 (2015): 3704-3739.

Card, David. "Immigrant inflows, native outflows, and the local labor market impacts of higher immigration." *Journal of Labor Economics* 19, no. 1 (2001): 22-64.

Clemens, Michael A., Ethan G. Lewis, and Hannah M. Postel. "Immigration restrictions as active labor market policy: Evidence from the Mexican bracero exclusion." *American Economic Review* 108, no. 6 (2018): 1468-1487.

Cornelissen, Thomas, Mimosa Distefano, Christian Dustmann, and Uta Schönberg. The effects of business taxation on local labor markets, firms and workers' careers." Working Paper (2025).

Criscuolo, Chiara, Ralf Martin, Henry G. Overman, and John Van Reenen. "Some causal effects of an industrial policy." *American Economic Review* 109, no. 1 (2019): 48-85.

Domini, Giacomo, Marco Grazzi, Daniele Moschella, and Tania Treibich. "Threats and opportunities in the digital era: Automation spikes and employment dynamics." *Research Policy* 50, no. 7 (2021): 104137.

Dube, Arindrajit, and Attila Lindner. "Minimum wages in the 21st century." *Handbook of Labor Economics* 5 (2024): 261-383.

Gechert, Sebastian, Tomas Havranek, Zuzana Irsova, and Dominika Kolcunova. "Measuring capital-labor substitution: The importance of method choices and publication bias." *Review of Economic Dynamics* 45 (2022): 55-82.

Gray, Rowena, Giulia Montresor, and Greg C. Wright. "Processing immigration shocks: Firm responses on the innovation margin." *Journal of International Economics* 126 (2020): 103345.

Gruber, Jonathan. "The incidence of payroll taxation: Evidence from Chile." *Journal of Labor Economics* 15, no. S3 (1997): S72-S101.

Hegna, Torje, and Karen Helene Ulltveit-Moe. "Reduced R&D Investments: A flip side of immigration?" No. 16325. CEPR Discussion Papers, 2021.

Hémous, David, and Morten Olsen. "The rise of the machines: Automation, horizontal innovation, and income inequality." *American Economic Journal: Macroeconomics* 14, no. 1 (2022): 179-223.

Hémous, David, Morten Olsen, Carlo Zanella, and Antoine Dechezleprêtre. “Induced automation innovation: Evidence from firm-level patent data.” *Journal of Political Economy* 133, no. 6 (2025).

Hubmer, Joachim, and Pascual Restrepo. “Not a typical firm: The joint dynamics of firms, labor shares, and capital–labor substitution.” No. w28579. National Bureau of Economic Research, 2021.

Kang, Dongik, Jung Hyuk Lee, and Simon Quach. “The welfare effects of a robot tax: Evidence from a tax credit for automation technologies in Korea.” Working paper (2025), University of Southern California.

Knoblach, Michael, Martin Roessler, and Patrick Zwerschke. “The elasticity of substitution between capital and labour in the US economy: A meta-regression analysis.” *Oxford Bulletin of Economics and Statistics* 82, no.1 (2020): 62-82.

Ku, Hyejin, Uta Schönberg, and Ragnhild C. Schreiner. “Do place-based tax incentives create jobs?.” *Journal of Public Economics* 191 (2020): 104105.

Kugler, Adriana, and Maurice Kugler. “Labor market effects of payroll taxes in developing countries: Evidence from Colombia.” *Economic Development and Cultural Change* 57, no. 2 (2009): 335-358.

Lafortune, Jeanne, Ethan Lewis, and José Tessada. “People and machines: A look at the evolving relationship between capital and skill in manufacturing, 1860–1930, using immigration shocks.” *Review of Economics and Statistics* 101, no. 1 (2019): 30-43.

Levinsohn, James, and Amil Petrin. “Estimating production functions using inputs to control for unobservables.” *Review of Economic Studies* 70, no. 2 (2003): 317-341.

Lewis, Ethan. “Immigration, skill mix, and capital skill complementarity.” *Quarterly Journal of Economics* 126, no. 2 (2011): 1029-1069.

Lichter, Andreas, Andreas Peichl, and Sebastian Siegloch. "The own-wage elasticity of labor demand: A meta-regression analysis." *European Economic Review* 80 (2015): 94-119.

Lobel, Felipe. "Who benefits from payroll tax cuts? Market power, tax incidence and efficiency." Working paper (2024).

Moll, Benjamin, Lukasz Rachel, and Pascual Restrepo. "Uneven growth: automation's impact on income and wealth inequality." *Econometrica* 90, no. 6 (2022): 2645-2683.

Olley, G. Steven, and Ariel Pakes. "The dynamics of productivity in the telecommunications equipment industry." *Econometrica* 64, no. 6 (1996): 1263-1297.

Quach, Simon. "Wage hysteresis and entitlement effects: The persistent impacts of a Temporary overtime policy." *Quarterly Journal of Economics* 140, no. 2 (2025): 1633-1680.

San, Shmuel. "Labor supply and directed technical change: Evidence from the termination of the bracero program in 1964." *American Economic Journal: Applied Economics* 15, no. 1 (2023): 136-63.

Saez, Emmanuel, Benjamin Schoefer, and David Seim. "Payroll taxes, firm behavior, and rent sharing: Evidence from a young workers' tax cut in Sweden." *American Economic Review* 109, no. 5 (2019): 1717-1763.

Saez, Emmanuel, Benjamin Schoefer, and David Seim. "Hysteresis from employer subsidies." *Journal of Public Economics* 200 (2021): 104459.

Silva, JMC Santos, and Silvana Tenreyro. "The log of gravity." *Review of Economics and Statistics* 88, no. 4 (2006): 641-658.

Zwick, Eric, and James Mahon. "Tax policy and heterogeneous investment behavior." *American Economic Review* 107, no. 1 (2017): 217-248.

TABLE 1: Treated vs Control Firms in 2003

	(1) Treated Firms stat. tax incr. > 3 pp.	(2) Control Firms stat. tax incr. < 3 pp.
A. Firm characteristics		
Statutory tax rate 2003 (%)	7.899	13.623
Change in stat. tax rate 03-07 (pp.)	6.112	0.276
Hourly wage rate	22.005 [4.28]	24.554 [6.00]
Workers (full-time equivalents)	45.595	50.005
Share of importing firms	0.634	0.679
Share of firms importing automation goods	0.230	0.292
Industries:		
Manufacturing	0.310	0.234
Construction	0.208	0.139
Agent- and wholesale/retail	0.216	0.295
Services	0.215	0.260
Other	0.052	0.073
Number of firms	2,016	9,852
B. R&D survey		
Share of firms investing in R&D	0.475	0.401
R&D investment (if positive)	527.376 [1070.62]	834.365 [1445.64]
R&D inv. per worker (if positive)	9.563 [18.08]	13.873 [24.94]
Number of firms	382	1,908

Notes : Panel A shows descriptive statistics for the sample of 11,868 firms with a wage bill exceeding 3 million NOK (423,729 USD) in 2003. Firms are classified into treated and control groups based on whether their average payroll tax rate is predicted to increase by at least three percentage points (treated) or by less than three percentage points (control) between 2003 and 2007. All variables and sample sizes are measured in 2003, and means are weighted by the number of workers (full-time equivalents) in the firm in 2003. Panel B shows data on R&D activities for a subset of 2,290 firms that are included in the 2003 R&D survey. R&D investments are total annual investments in 1,000 USD (using the exchange rate for 2003; 1 USD = 7.08 NOK). Standard deviations in brackets.
Data sources : Norwegian register data and R&D survey made available by Statistics Norway.

TABLE 2: The Effects of Payroll Taxes on Wages and Employment

	(1)	(2)	(3)	(4)
	A. Log hourly wages (firm level)			
	1999-2010	1999-2006	1999-2010 excl. 2004-2006	FD, 2006 vs 2003
Treated x Post	0.005	0.000	0.008	0.003
	(0.005)	(0.005)	(0.007)	(0.004)
Observations	121,273	85,267	89,363	10,103
Firm FE	Yes	Yes	Yes	N/A
	B. Log employment (firm level)			
	1999-2010	1999-2006	1999-2010 excl. 2004-2006	FD, 2006 vs 2003
Treated x Post	-0.060**	-0.058***	-0.058*	-0.070***
	(0.024)	(0.018)	(0.035)	(0.020)
Observations	121,273	85,267	89,363	10,103
Firm FE	Yes	Yes	Yes	N/A
	C. Log hourly wage (worker level)			
	1999-2010	1999-2006	1999-2010 excl. 2004-2006	FD, 2006 vs 2003
Treated x Post	-0.009	-0.008	-0.010	-0.000
	(0.007)	(0.007)	(0.008)	(0.009)
Observations	3,906,279	2,574,952	2,848,931	192,921
Firm FE	Yes	Yes	Yes	N/A
Workers FE	Yes	Yes	Yes	Firm Stayers

Notes: The table shows the DID estimates of β in equation (5), where treated (control) firms experienced an increase in their expected average payroll tax rate of at least (less than) 3 percentage points between 2003 and 2007, and the post period refers to 2004 and onwards. Panels A and B use firms as the unit of analysis, and the dependent variables are the firm's average log hourly wage and the firm's log employment. Panel C conducts analysis at the worker level, using the worker's log hourly wage as the outcome variable and including worker fixed effects to account for changes in the firm's workforce composition. The baseline sample in column (1) includes the years 1999-2010. Column (2) restricts the sample to the years 1999-2006, excluding the period during which the payroll tax rate was reversed to the pre-policy level. Column (3) excludes the policy years 2004-2006 instead. Column (4) shows results from a first-difference specification focusing on the difference between 2003 and 2006. In column (3) of Panel C, the sample includes workers who, in 2006, were still employed in their 2003 firm (stayers), thus holding the firm's workforce composition constant. Firm-level regressions are weighted by the number of workers (full-time equivalents) in the firm in 2003. Robust standard errors clustered by the firm's commuting zone in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Data sources : Norwegian register data made available by Statistics Norway.

TABLE 3: The Effects of Payroll Taxes on Automation and R&D

	(1) Automation imports	(2) Any imports	(3) Any R&D	(4) Log R&D investment	(5) R&D investment (Poisson)	(6) Log R&D Workers
Treated x Post	0.021***	0.012	-0.071**	0.228***	0.187***	0.218**
	(0.008)	(0.008)	(0.026)	(0.076)	(0.068)	(0.095)
Firm FE	Yes	Yes	No	No	No	No
Sector FE	No	No	Yes	Yes	Yes	Yes
Observations	121,273	121,273	21,246	6,939	21,246	6,638
Model	OLS	OLS	OLS	OLS	Poisson	OLS
Dep. var. mean in 2003	0.235	0.616	0.359	227.6	227.6	1.563

Notes: This table shows the DID estimates of β in equation (5), where treated (control) firms experienced an increase in their expected average payroll tax rate of at least (less than) 3 percentage points between 2003 and 2007, and the post period refers to 2004 and onwards. Columns (1) and (2) include the full sample of firm-by-year observations. Automation imports in column (1) indicate whether the firm imported any automation goods in that year; the list of automation goods is provided in Appendix Table A.1. Any imports in column (2) indicate whether the firm imported any goods in that year. Columns (3) to (6) are based on a subset of firm-years included in the annual R&D survey (conducted in each year between 1999 and 2010, except for 2000). For this subsample, we condition on sector fixed effects (12 categories based on 1-2-digit NACE codes) rather than firm fixed effects, since the R&D survey is not a rotating panela with limited longitudinal tracking of firms. and the number of firms represented in both the pre- and post-2004 periods is limited. In column (3), the dependent variable indicates whether the firm made any R&D investments in that year. In column (4), the sample is restricted to firms with positive R&D investments and uses the log of R&D investments per year, measured in 1,000 USD (using the 2003 exchange rate; 1 USD = 7.08 NOK), as the dependent variable. Column (5) uses a Poisson regression to include firms with zero investment. Column (6) uses the number of R&D workers in logs as the dependent variable, restricting the sample to firms with at least one R&D worker. The dependent variable means at the bottom of the table refer to the year 2003. For ease of interpretation, in columns (4) and (6), the means refer to the means of R&D investment and R&D workers, not the means of the log of these variables. All regressions are weighted by the number of workers (full-time equivalents) in the firm in 2003. Robust standard errors clustered by the firm's commuting zone in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Data sources : Norwegian register data, customs data, and the R&D survey made available by Statistics Norway.

TABLE 4: The Effects of Payroll Taxes on Firm Innovation

	(1) Process innovation	(2) Labor-cost reducing innovation	(3) Product Innovation	(4) New-to-the-Market Innovation
Treated x Post	0.076*	0.073*	-0.011	-0.015
	(0.044)	(0.041)	(0.033)	(0.040)
Observations	8,129	8,129	8,129	8,129
Sector FE	Yes	Yes	Yes	Yes
Mean (2001 wave)	0.389	0.190	0.288	0.190

Notes: The table shows the DID estimates of β in equation (5), where treated (control) firms experienced an increase in their expected average payroll tax rate of at least (less than) 3 percentage points between 2003 and 2007, and the post period refers to 2004 and onwards. The sample is a subset of firms included in the 2001, 2006, 2008, and 2010 waves of the Community Innovation Survey (CIS). Each wave refers to innovation activities that occurred in the current and in the previous two years. The 2004 wave, which includes activities for both pre- and post-reform periods, is excluded. All regressions condition on sector FE (12 categories based on 1-2-digit NACE codes) rather than firm fixed effects, since the number of firms included in both the pre- and post-policy periods is limited. The dependent variables across columns refer to different types of innovation. Details of the survey questions are provided in Appendix Table A.5. The means at the bottom of the table refer to the means from the 2001 wave. All regressions are weighted by the number of workers (full-time equivalents) in the firm in 2003. Robust standard errors clustered by the firm's commuting zone in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Data sources: Norwegian register data and the Community Innovation Survey (CIS) made available by Statistics Norway.

TABLE 5: The Effects of Payroll Taxes on Firm Performance

	(1)	(2)	(3)	(4)	(5)	(6)
	Sales revenue	Capital investments	Capital investments per worker	Labor productivity	TFP	Labor share
Treated x Post	-0.004	0.070	0.139**	0.062**	0.004**	-0.050**
	(0.029)	(0.057)	(0.061)	(0.024)	(0.002)	(0.022)
Observations	111,690	86,924	86,924	111,149	99.958	111,139
Sample	1999-2010	1999-2010	1999-2010	1999-2010	1999-2010	1999-2010
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: The table shows the DID estimates of β in equation (5), where treated (control) firms experienced an increase in their expected average payroll tax rate of at least (less than) 3 percentage points between 2003 and 2007, and the post period refers to 2004 and onwards. The sample includes the full set of firms for which balance sheet data are available between 1999 and 2010. All outcome variables are in logs. In column (4), labor productivity is measured as value added per worker. In column (5), TFP is estimated using the Olley and Pakes (1996) control function method. The approach uses investments to proxy for unobserved productivity shocks. The results are robust to using the Levinsohn and Petrin (2003) method, which relies on intermediate-input demand as a proxy variable. In column (6), the labor share is computed as the gross total wage bill (inclusive of payroll taxes) over value added. Firm-level regressions are weighted by the number of workers (full-time equivalents) in the firm in 2003. Robust standard errors clustered by the firm's commuting zone in parentheses. Bootstrapped standard errors are reported when estimated TFP is used as the dependent variable (column (5)). *** p<0.01, ** p<0.05, * p<0.1

Data sources : Norwegian register data and firm balance sheet data made available by Statistics Norway.

TABLE 6: Large versus Medium-Sized Sirms

	(1)	(2)	(3)	(4)	(5)	(6)
	Large firms			Medium-sized firms		
	A. Wages and employment					
	Wages	Wages (Worker FE)	Employment	Wages	Wages (Worker FE)	Employment
Treated x Post	0.006	-0.010	-0.068**	-0.000	-0.006	-0.046**
	(0.006)	(0.008)	(0.030)	(0.008)	(0.006)	(0.019)
Observations	60,709	2,820,367	60,709	60,564	1,043,764	60,564
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Worker FE	No	Yes	No	No	Yes	No
	B. Automation, R&D and innovation					
	Automation	R&D (Poisson)	Process Innovation	Automation	R&D (Poisson)	Process Innovation
Treated x Post	0.036***	0.240***	0.080*	-0.007	-0.990***	-0.033
	(0.010)	(0.077)	(0.050)	(0.008)	(0.287)	(0.052)
Observations	60,709	15,223	5.803	60,564	5,957	2.326
Firm FE	Yes	No	No	Yes	No	No
Sector FE	No	Yes	Yes	No	Yes	Yes
	C. Labor productivity, TFP and labor share					
	Log labor productivity	Log TFP	Log labor share	Log labor productivity	Log TFP	Log labor share
Treated x Post	0.070**	0.005**	-0.069**	0.032*	0.001	-0.025*
	(0.028)	(0.002)	(0.031)	(0.017)	(0.002)	(0.015)
Observations	56,316	50.913	56,390	54,833	49,045	54,939
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: This table shows the DID estimates of β in equation (5), where treated (control) firms experienced an increase in their expected average payroll tax rate of at least (less than) 3 percentage points between 2003 and 2007, and the post period refers to 2004 and onwards. Regressions are estimated separately for large firms (columns (1)-(3)) and medium-sized firms (columns (4)-(6)). Firms are classified as large and medium-sized according to whether they are above or below the median in the 2003 firm wage-bill distribution. Firm-level regressions are weighted by the number of workers (full-time equivalents) in the firm in 2003. Robust standard errors clustered by the firm's commuting zone in parentheses. Bootstrapped standard errors are reported when estimated TFP is used as the dependent variable (Panel C, columns (2) and (5)). *** p<0.01, ** p<0.05, * p<0.1

Data sources: Norwegian register data, customs data, R&D survey, Community Innovation Survey, and firm balance sheet data made available by Statistics Norway.

TABLE 7: The Effects of Payroll Taxes on Incumbent Workers

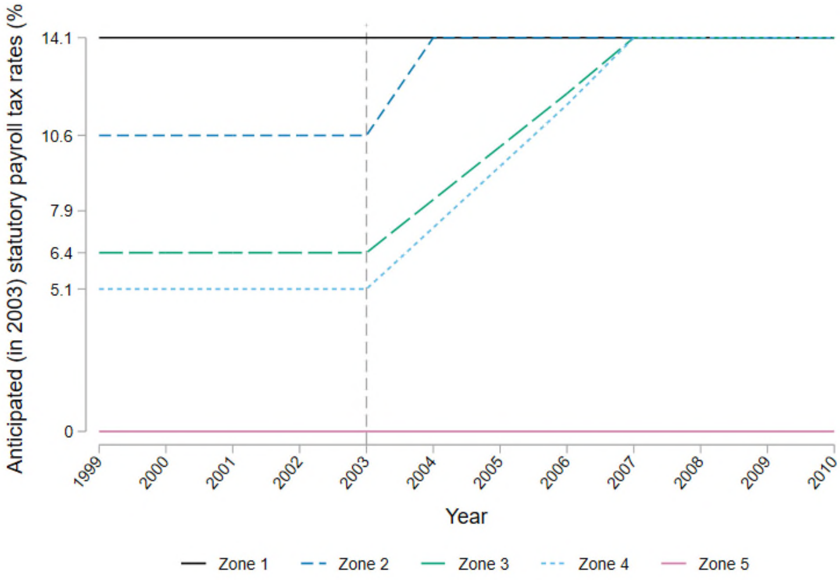
	(1)	(2)	(3)	(4)
	Employed	Wages relative to 2003 wage	Wages relative to 2003 wage, conditional on employment	Wages relative to 2003, conditional on staying at baseline firm
		A. Outcomes during Policy Years (2004-2006)		
Treated	-0.000	-0.000	0.001	0.002
	(0.003)	(0.007)	(0.005)	(0.003)
Observations	1,111,956	1,111,956	988,330	707,100
Mean	0.889	1.032	1.162	1.055
		B. Outcomes in Post-Policy Years (2007-2010)		
Treated	0.006	0.019	0.012	0.001
	(0.004)	(0.015)	(0.012)	(0.009)
Observations	1,482,608	1,482,608	1,225,444	524.58
Mean	0.827	1.211	1.466	1.302

Notes: This table compares wage and employment outcomes of incumbent workers employed by a treated or a control firm in 2003. Panel A measures worker outcomes during the policy years (2004-2006), when the higher payroll tax rates were in place. Panel B measures worker outcomes in the post-policy years (2007-2010), after payroll tax rates reverted to their original levels. In column (1), the dependent variable equals 1 if the worker is employed and zero otherwise. In columns (2)-(4), post-treatment wages are measured relative to wages in 2003. In column (2), wages are set to zero for those not employed. All regressions include the following control variables: age and tenure in the 2003 firm as quadratic polynomials, dummies for gender and being foreign-born, dummies for having a high school, college, or vocational education, wage in 2003, contract type in the 2003 firm (full-time, and two types of part-time contracts), and year dummies. Robust standard errors clustered by commuting zone in parentheses. *** p<0.01, ** p<0.05, * p<0.1

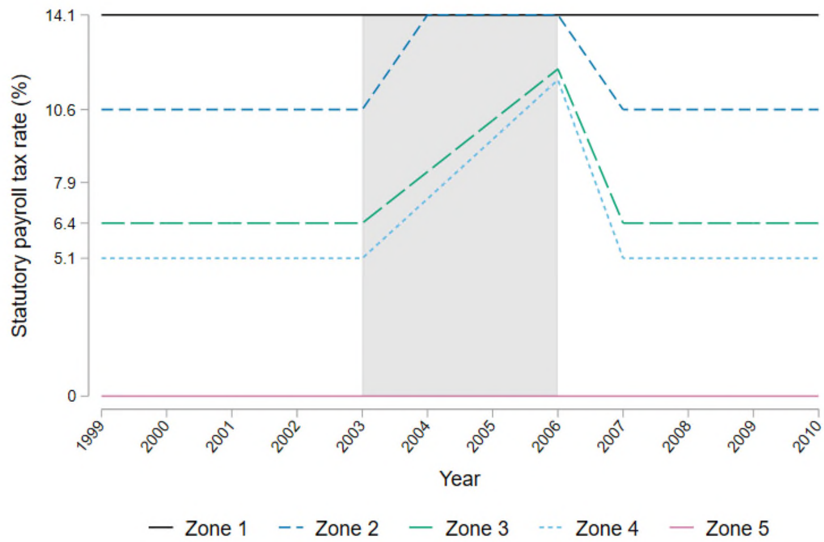
Data sources: Norwegian register data made available by Statistics Norway.

FIGURE 1: Payroll Tax Rates by Tax Zones (Zones 1 to 5)

A. Anticipated (in 2003) Payroll Tax Rates by Tax Zone



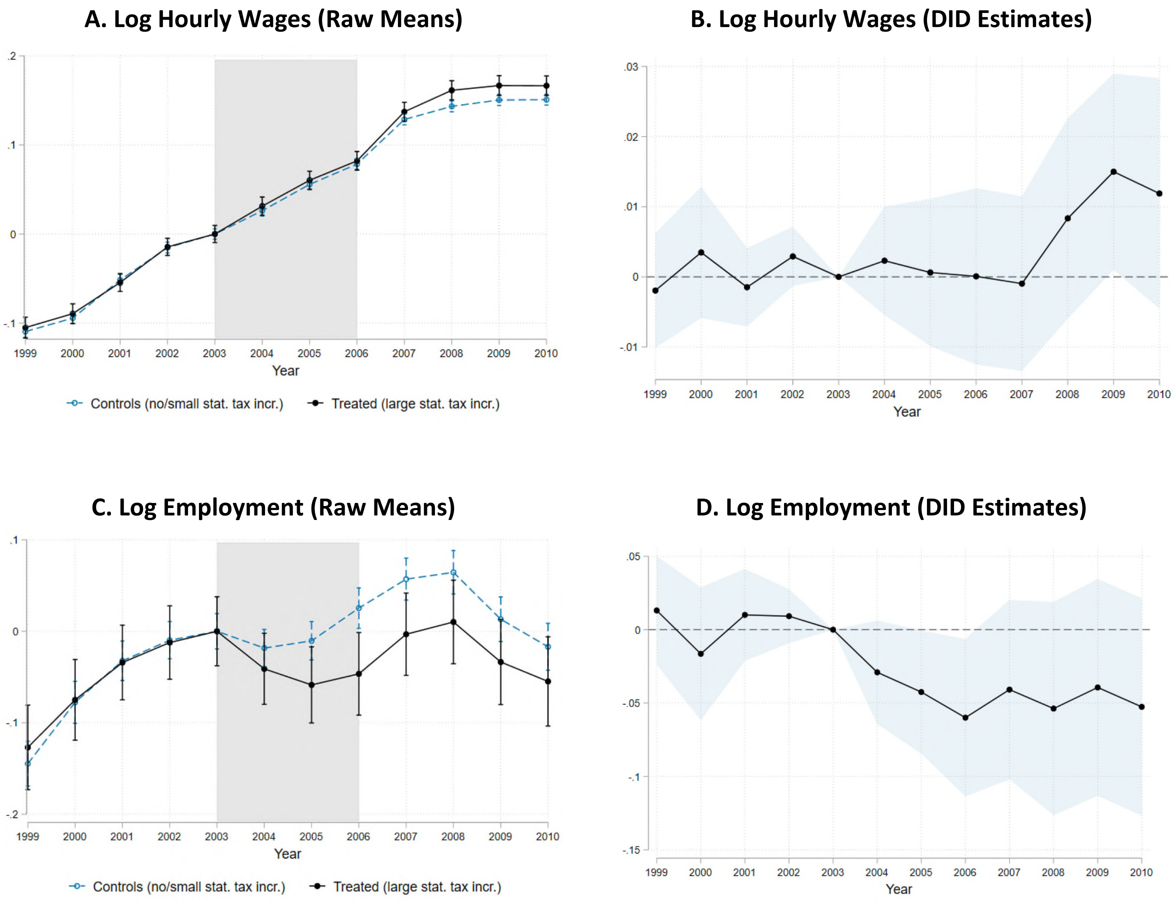
B. Realized Payroll Tax Rates by Tax Zone



Notes: The figure shows the evolution of the payroll tax rates by the five tax zones in Norway. Panel A shows the statutory tax rates as anticipated in 2003, at the time of the reform announcement. Panel B shows the realized statutory tax rates that prevailed in different tax zones. Tax rates range from 14.1% in zone 1 to 0% in zone 5 in the pre-reform years. According to the 2003 tax-harmonization reform instigated by a ruling by the EFTA Surveillance Authority (ESA), the tax rates were to gradually increase beginning in 2004 and fully harmonized across zones by 2007, with the exception of zone 5, which was allowed to keep a 0% tax rate (as in Panel A). In 2007, tax rates were unexpectedly reverted to pre-reform levels due to the EEA's updated Regional Aid Guidelines, effective January 1, 2007.

Data sources : The Norwegian Tax Authorities.

FIGURE 2: Wages and Emplyment in Treated and Control Firms over Time

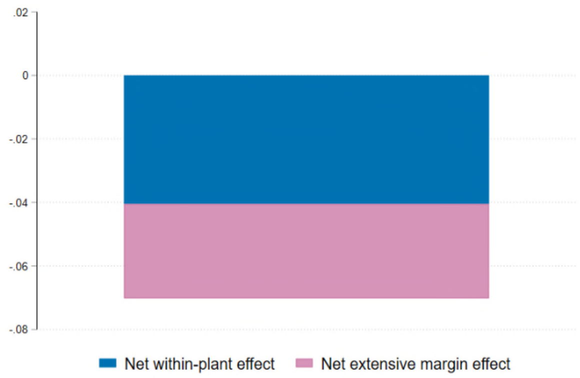


Notes: The figure presents the raw means (panels A and C) and the event-study estimates based on equation (4) (panels B and D), comparing outcomes at treated vs. control firms over time. Panels A and B show results for log hourly wages, and Panels C and D for log employment. Raw trends are based on a balanced sample of firms (1999-2010), with the 2003 means normalized to zero. The gray-shaded area indicates the reform period during which payroll taxes were elevated. Event-study regressions are based on the full sample of firms and include firm fixed effects and sector-by-year fixed effects. Confidence intervals (blue-shaded areas) are shown at the 95% significance level. Both raw means and DID estimates are weighted by the firm's 2003 number of workers (full-time equivalents).

Data sources: Norwegian register data made available by Statistics Norway.

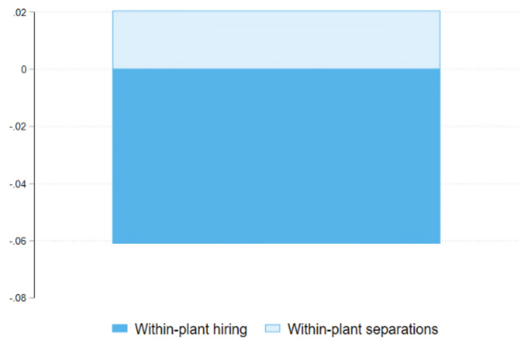
FIGURE 3: Decomposition of the Overall Employment Decline

A. Within-Plant Adjustments vs. Plant Entry and Exit



B. Plant Entry vs. Exit

C. Within-Plant Hirings vs. Separations

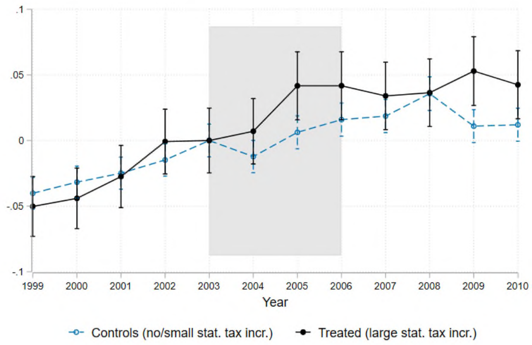


Notes: The figure shows various decompositions of the overall employment decline in the firm induced by the payroll tax increase, based on a balanced panel of firms observed in 2003 and 2006 (see column (3) of Panel C in Table 2). Panel A decomposes the overall employment decline into within-plant adjustments (the intensive margin) and plant entry and exit (the extensive margin). Panel B decomposes the extensive margin effect into plant entry vs. plant exit. Panel C further decomposes the within-plant adjustments into hiring and separations.

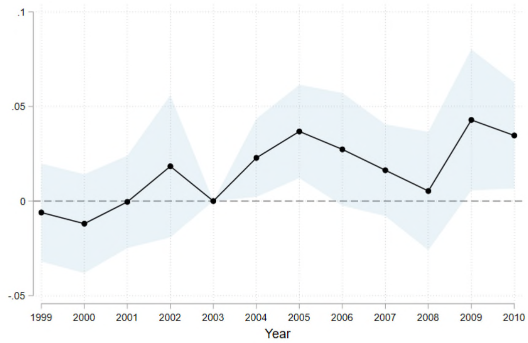
Data sources: Norwegian register data made available by Statistics Norway.

FIGURE 4: Automation Imports in Treated and Control Firms

A. Automation Imports (Raw Means)



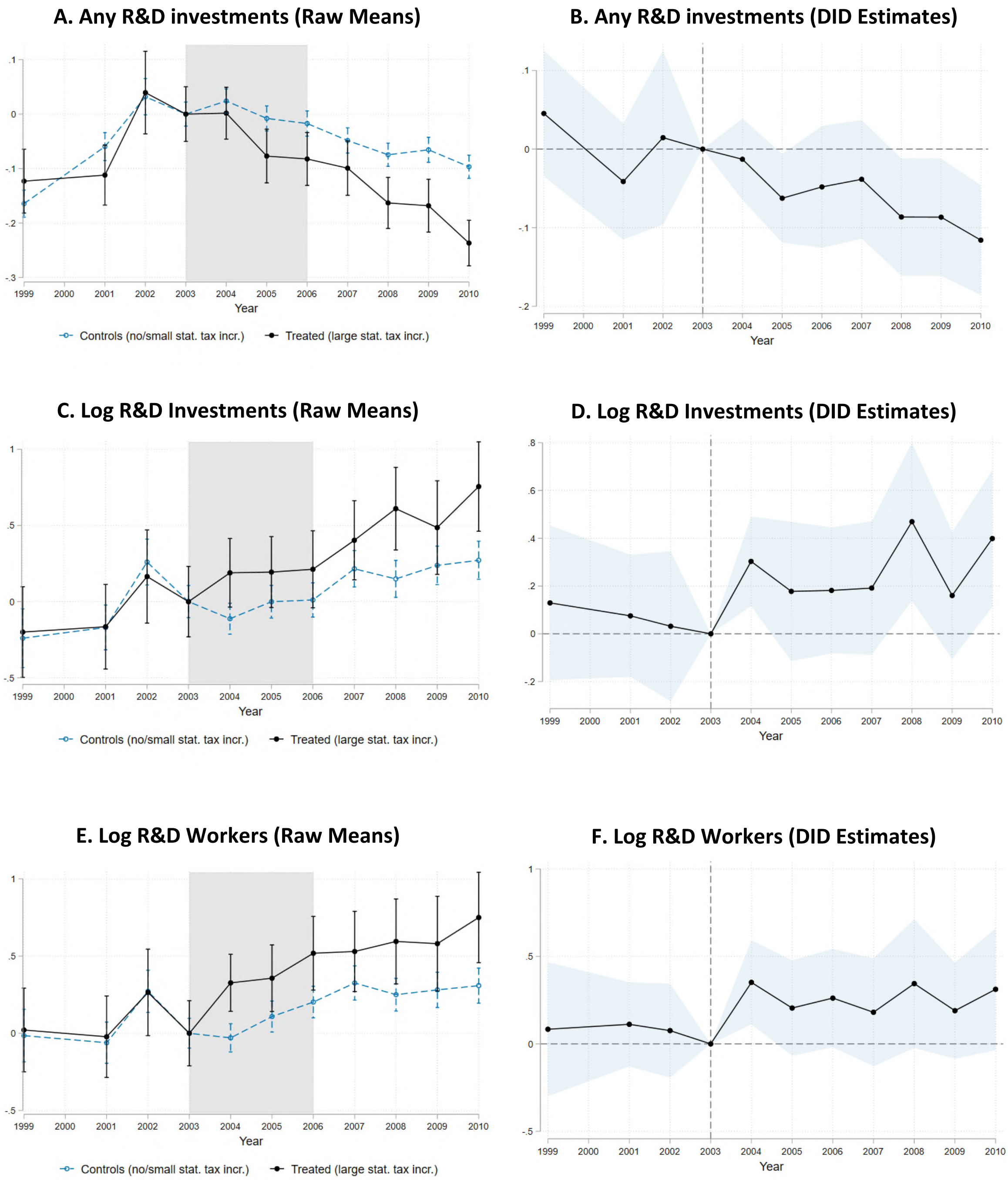
B. Automation Imports (DID Estimates)



Notes: The figure presents the raw means (panel A) and the event-study estimates based on equation (4) (panel B), comparing automation imports in treated and control firms over time. Automation imports indicate whether the firm imported any automation goods (listed in Appendix Table A.1) in that year. Raw trends are based on a balanced sample of firms (1999-2010), with the 2003 means normalized to zero. The gray-shaded area indicates the reform period during which payroll taxes were raised. Event-study regressions are based on the full sample of firms, and include firm fixed effects and sector-by-year fixed effects. Confidence intervals (blue-shaded areas) are shown at the 95% significance level. Both raw means and DID estimates are weighted by the firm's 2003 number of workers (full-time equivalents).

Data sources: Norwegian register data made available by Statistics Norway.

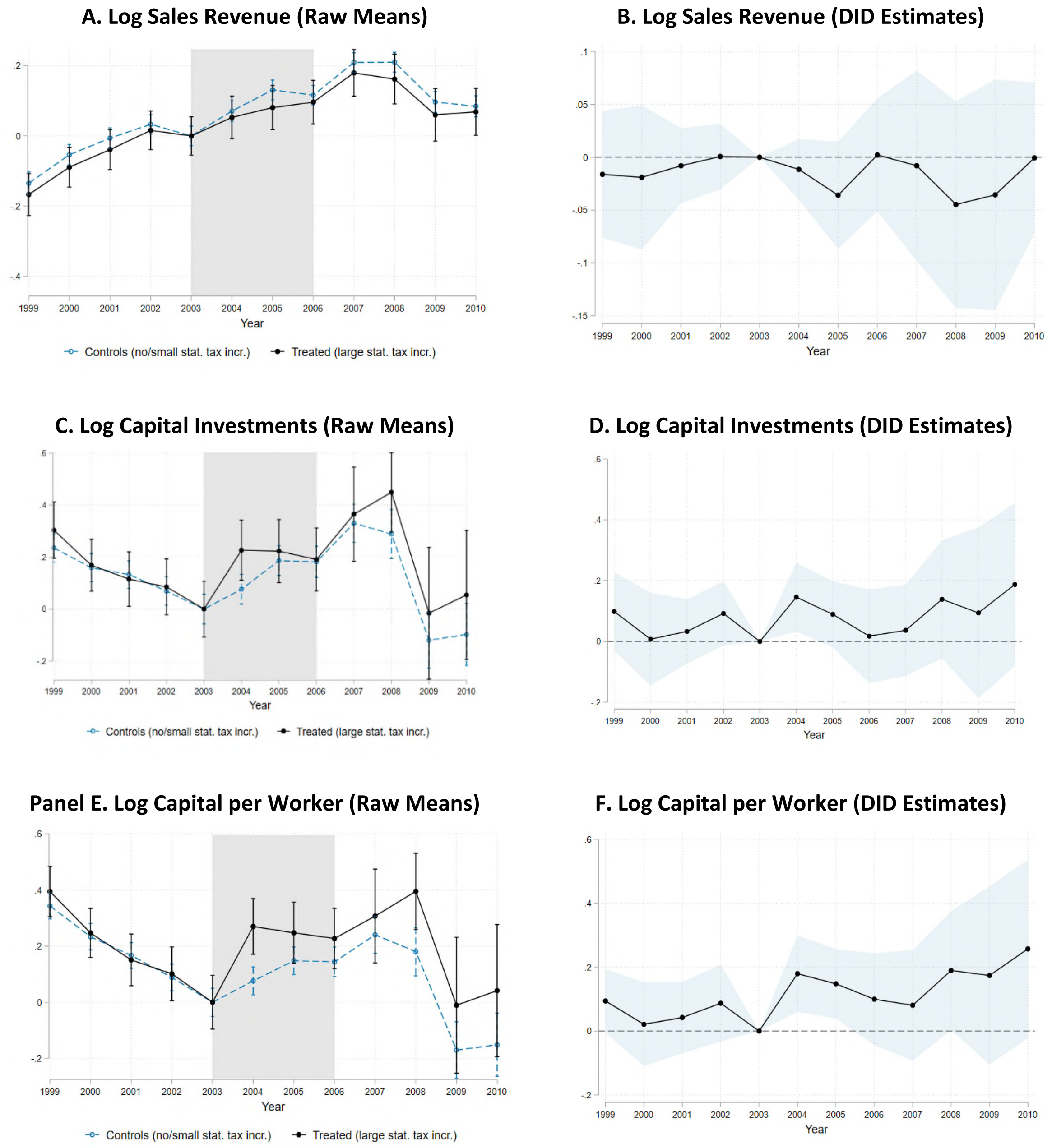
FIGURE 5: R&D Investments in Treated and Control Firms



Notes: This figure presents the raw means (panels A, C, and E) and the event-study estimates based on equation (4) (panels B, D, and F), comparing outcomes at treated vs. control firms over time. Panels A and B report results on the extensive margin; that is, whether the firm invests in R&D in that year. Panels C and D restrict the sample to firms with positive R&D investments and use the log of these investments as the outcome. Panels E and F restrict the sample to firms with at least one R&D worker and use log R&D workers as the outcome. Raw trends are based on the full sample of firms observed in the R&D survey, with the 2003 means normalized to zero. The gray-shaded area indicates the reform period during which payroll taxes were raised. Event-study regressions are based on the same sample and include sector- and year-fixed effects. Confidence intervals (blue- shaded areas) are shown at the 95% significance level. Both raw means and DID estimates are weighted by the firm's 2003 number of workers (full-time equivalents).

Data sources: Norwegian register data made available by Statistics Norway.

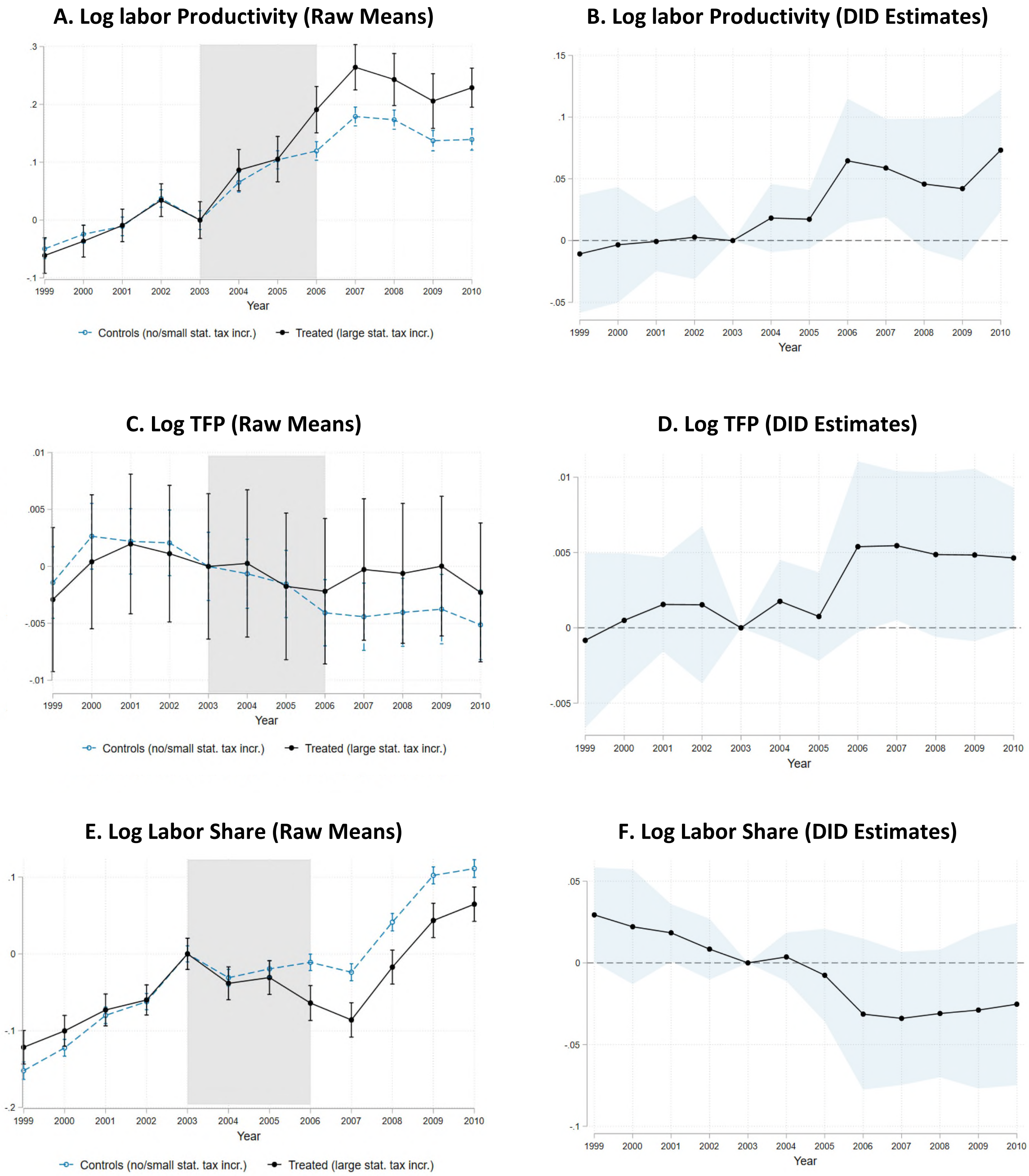
FIGURE 6: Firm Performace in Treated and Control Firms



Notes: The figure presents the raw means (panels A, C, and E) and the event-study estimates based on equation (4) (panels B, D, and F), comparing outcomes at treated vs. control firms over time. Panels A and B show results for log sales revenue, panels C and D for log capital investments, and panels E and F for log capital per worker. Raw trends are based on a balanced sample of firms (1999-2010), with the 2003 means normalized to zero. The gray-shaded area indicates the reform period during which payroll taxes were raised. Event study regressions are based on the full sample of firms, and include firm fixed effects and sector-by-year fixed effects. Confidence intervals (blue- shaded areas) are shown at the 95% significance level. Both raw means and DID estimates are weighted by the firm's 2003 number of workers (full-time equivalents).

Data sources: Norwegian register data made available by Statistics Norway.

FIGURE 7: Labor Productivity, TFP, and the Labor Share in Treated and Control Firms



Notes: The figure presents the raw means (panels A, C, and E) and the event-study estimates based on equation (4) (panels B, D, and F), comparing outcomes at treated vs. control firms over time. Panels A and B show results for log labor productivity, panels C and D for log total factor productivity (TFP), and panels E and F for the log labor share. Raw trends are based on a balanced sample of firms (1999-2010), with the 2003 means normalized to zero. The gray-shaded area indicates the reform period during which payroll taxes were raised. Event studies are based on the full sample of firms, and include firm fixed effects and sector-by-year fixed effects. Confidence intervals are for 95% significance level. Both raw means and DID estimates are weighted by the firm's 2003 number of workers (full-time equivalents).

Data sources: Norwegian register data made available by Statistics Norway.

Appendix A: Additional Tables and Figures

TABLE A.1: The Community Innovation Survey (CIS)

Type of innovation	Survey question
Process innovation A process innovation is the implementation of a new or significantly improved production process, distribution method, or support activity for your goods or services. The innovation (new or improved) must be new to your enterprise, but it does not need to be new to your sector or market. It does not matter if the innovation was originally developed by your enterprise or by other enterprises. Exclude purely organisational innovations.	During the three years 2004 to 2006, did your enterprise introduce: 1. New or significantly improved methods of manufacturing or producing goods or services? 2. New or significantly improved logistics, delivery or distribution methods for your inputs, goods or services? 3. New or significantly improved supporting activities for your processes, such as maintenance systems or operations for purchasing, accounting, or computing?
Labor-cost saving innovation	How important were each of the following effects of your product (good or service) and process innovations introduced during the three years 2004 to 2006? Reduce labor costs per unit output.
Product innovation A product innovation is the market introduction of a new good or service or a significantly improved good or service with respect to its capabilities, such as improved software, user friendliness, components or sub-systems. The innovation (new or improved) must be new to your enterprise, but it does not need to be new to your sector or market. It does not matter if the innovation was originally developed by your enterprise or by other	During the three years 2004 to 2006, did your enterprise introduce: 1. New or significantly improved goods (exclude the simple resale of new goods purchased from other enterprises and changes of a solely aesthetic nature)? 2. New or significantly improved services?
New-to-the-market innovation	Were any of your goods and service innovations during the three years 2004 to 2006 new to your market? Your enterprise introduced a new or significantly improved good or service onto your market before your competitors (it may have already been available in other markets).

Notes: The table provides a description of the variables from the CIS, as well as the survey questions in the 2006 CIS wave.
Source : https://ec.europa.eu/eurostat/cache/website/cis/Surveys/Survey_CIS2006_6_doc.html

TABLE A.2: HS-Codes for Labor-Automating Intermediate Goods

Label	HS-codes
Industrial robots	84795000
Dedicated machinery (superset of industrial robots)	84798900, 84795900, 84799080
Numerically controlled machines	84563011, 84563019, 84573010, 845811, 845891, 845921, 845931, 84594010, 845951, 845961, 846011, 846021, 846031, 84604010, 84613010, 84614011, 84614031, 84614071, 84621010, 846221, 846231, 846241, 84629120, 84629920, 84561100, 84569000, 84571010, 84581000, 84594100, 84601200, 84622900, 84623900, 84624900
Machine tools (excl. codes for numerically controlled machines)	845600–846899, 845700–845799, 851500–851599, 84629100, 84629900, 84632000, 84651010, 84659100, 84659200, 84659300, 84659900, 84793000, 84794000, 84501111, 84512100, 84518000, 84519000, 85141010, 85269180, 85269200, 85371099, 85372000, 85389099
Tools for industrial work	820200–821299
Welding machines	851521–851590
Weaving machines	844600–844699
Knitting machines	844700–844799
Other textile dedicated machinery	844400–845399, 84418000, 84419000, 84451900
Conveyors	842511–842839, 84251111, 84314210, 84314980
Regulating instruments	902500–903299, 90318099, 90328900, 90329900

Notes: The table lists the 2012-HS codes for Labor-Automating Intermediate Goods. The categories follow the automation goods classification of Acemoglu and Restrepo (2022), as operationalized by Domini et al. (2021).

TABLE A.3: The Effects of Payroll Taxes on Firm Outcomes: Continuous Treatment Variable

	(1)	(2)	(3)
		A. Wages and employment	
	Log hourly wage	Log hourly wage	Log employment
Predicted tax change x Post	0.001	-0.001	-0.009**
	(0.001)	(0.001)	(0.004)
Observations	121,273	3,906,279	121,273
Sample	1999-2010	1999-2010	1999-2010
Firm FE	Yes	Yes	Yes
Worker FE	N/A	Yes	N/A
		B. Automation, R&D investment, and innovation	
	Automation imports	R&D costs (Poisson)	Process innovation
Predicted tax change x Post	0.002	0.023**	0.017**
	(0.001)	(0.009)	(0.007)
Observations	121,273	21,246	8,129
Sample	1999-2010	1999-2010	1999-2010
Firm FE	Yes	No	No
Sector FE	No	Yes	Yes
		C. Labor productivity, TFP, and the labor share	
	Log Labor Productivity	Log TFP	Log labor share
Predicted tax change x Post	0.009***	0.0006***	-0.007***
	(0.003)	(0.0002)	(0.003)
Observations	111,149	99.958	111,139
Sample	1999-2010	1999-2010	1999-2010
Firm FE	Yes	Yes	Yes

Notes: The table presents estimates of key outcomes using the continuous counterpart of our main binary treatment indicator. The continuous treatment variable captures the change in the predicted average tax rate for firms from 2003 to 2007 as defined in equation (2). In panel C, column (2), TFP is estimated using the Olley and Pakes (1996) control function method. All regressions are at the firm level except for Panel A, column (2), which is estimated at the worker level. Firm-level regressions are weighted by the firm's 2003 number of workers (full-time equivalents). Robust standard errors clustered by commuting zone in parentheses. Bootstrapped standard errors are reported when estimated TFP is used as the dependent variable (panel C, column (2)). *** p<0.01, ** p<0.05, * p<0.1

Data sources: Norwegian register data, customs data, R&D survey, Community Innovation Survey, and firm balance sheet data made available by Statistics Norway.

TABLE A.4: The Effects of Payroll Taxes on Wages and Employment - Robustness

	(1) Baseline	(2) Sector-by-Year FE	(3) Controls for Immigration	(4) Excl. petroleum sectors
		A. Log hourly wage		
Treated x Post	0.005	0.005	-0.001	0.008
	(0.005)	(0.005)	(0.004)	(0.005)
Observations	121,273	121,264	121.273	112,897
		B. Log employment		
Treated x Post	-0.060**	-0.056**	-0.064**	-0.060**
	(0.024)	(0.025)	(0.027)	(0.027)
Observations	121,273	121,264	121.273	112,897
Sample	Baseline	Baseline	Baseline	Excl. petroleum sectors
Firm FE	Yes	Yes	Yes	Yes
Sector-by-year FE	No	Yes	No	No
Imm. share-by-year FE	No	No	Yes	No

Notes: The table examines the robustness of our main wage and employment estimates using the full sample of firms. Panel A uses the firm's average log hourly wage as the dependent variable, while Panel B focuses on log employment. Column (1) shows our baseline estimates (see column (1) of Table 2, panels A and B). Column (2) controls for sector-by-year fixed effects (instead of year fixed effects in the baseline). Column (3) includes interactions between the 2003 EU8 shares in the firm's region and year FEs. EU8 refers to the eight Central and Eastern European countries that joined the EU in 2004, excluding Malta and Cyprus. Column (4) excludes petroleum sectors. All regressions are weighted by the firm's 2003 number of workers (full-time equivalents). Robust standard errors clustered by commuting zone in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Data sources: Norwegian register data made available by Statistics Norway.

TABLE A.5: The Effects of Payroll Taxes on Automation, Productivity, and the Labor Share - Robustness

	(1)	(2)	(3)	(4)
	Baseline	Sector-by-Year FE	Controls for Immigration	Excl. petroleum sectors
		A. Automation imports		
Treated x Post	0.021***	0.021***	0.021**	0.018**
	(0.008)	(0.008)	(0.008)	(0.008)
Observations	121,273	121,264	121,273	112,897
		B. R&D investments (Poisson)		
Treated x Post	0.215***	0.195**	0.168**	0.299***
	(0.069)	(0.090)	(0.076)	(0.081)
Observations	21,246	21,230	21,246	17,530
		C. Log labor productivity		
Treated x Post	0.062**	0.063**	0.039**	0.056**
	(0.024)	(0.024)	(0.021)	(0.025)
Observations	111,149	111,145	111,149	103,018
		D. Log TFP		
Treated x Post	0.005**	0.005**	0.003*	0.004**
	(0.002)	(0.002)	(0.002)	(0.002)
Observations	99,946	99,943	99,958	92.055
		E. Log labor share		
Treated x Post	-0.056**	-0.057**	-0.037*	-0.052**
	(0.024)	(0.023)	(0.021)	(0.025)
Observations	111,149	111,145	111,149	103,018

Notes: The table examines the robustness of our main estimates for automation, R&D investments, labor productivity, total factor productivity, and the labor share. With the exception of R&D investments in panel B, outcomes are measured in logs and based on the full sample of firms. Panel B is based on a subset of firm-years included in the annual R&D survey (conducted in each year between 1999 and 2010, except for 2000). For this subsample, we condition on sector fixed effects (12 categories based on 1-2-digit NACE codes) rather than firm fixed effects and estimate Poisson models. Column (1) repeats our baseline estimates for the different outcomes. Column (2) includes controls for sector-by-year fixed effects (instead of year fixed effects in the baseline). Column (3) includes interactions between the 2003 EU-8 shares in the firm's region and year FEs. EU-8 refers to the eight Central and Eastern European countries that joined the EU in 2004, excluding Malta and Cyprus. Column (4) excludes petroleum sectors. All regressions are weighted by the firm’s 2003 number of workers (full-time equivalents). Robust standard errors clustered by commuting zone in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Data sources: Norwegian register data, customs data, R&D survey, Community Innovation Survey, and firm balance sheet data made available by Statistics Norway.

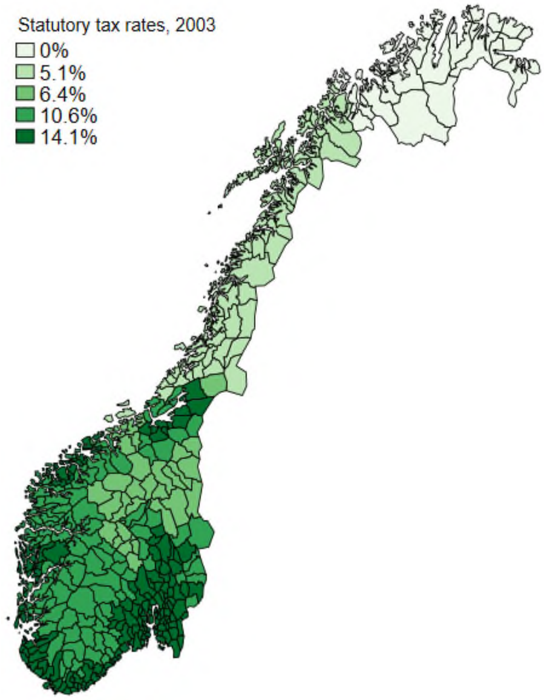
TABLE A.6: Descriptive Statistics by Firm Size

	(1)	(2)	(3)	(4)
	Treated Firms stat. tax incr. > 3 pp.		Control Firms stat. tax incr. < 3 pp.	
	Medium Firms	Large Firms	Medium Firms	Large Firms
A. Firm characteristics				
Statutory tax rate 2003 (%)	7.600	8.048	13.584	13.638
Change in stat. tax rate 03-06 (pp.)	6.410	5.963	0.218	0.298
Hourly wage rate	20.930 [4.13]	22.540 [4.25]	22.498 [5.65]	25.306 [5.95]
Workers (full time equivalents)	20.167	58.262	20.310	60.864
Share of importing firms	0.470	0.715	0.510	0.740
Share of firms automation-importing firms	0.111	0.289	0.144	0.346
Industries				
Manufacturing	0.209	0.360	0.150	0.264
Construction	0.218	0.203	0.153	0.133
Agent- and wholesale/retail	0.281	0.183	0.336	0.280
Services	0.224	0.210	0.265	0.258
Other	0.068	0.044	0.096	0.064
B. R&D survey				
Share of firms investing in R&D	0.271	0.512	0.202	0.425
R&D inv.G4 (if pos.)	271.502 [351.16]	551.778 [1113.42]	267.501 [275.41]	866.139 [1477.98]
R&D inv. per worker (if pos.)	17.368 [27.56]	8.818 [16.77]	19.458 [22.72]	13.560 [25.03]
Number of firms	1115	901	4817	5035
Firms in 2003-R&D survey	141	241	559	1349

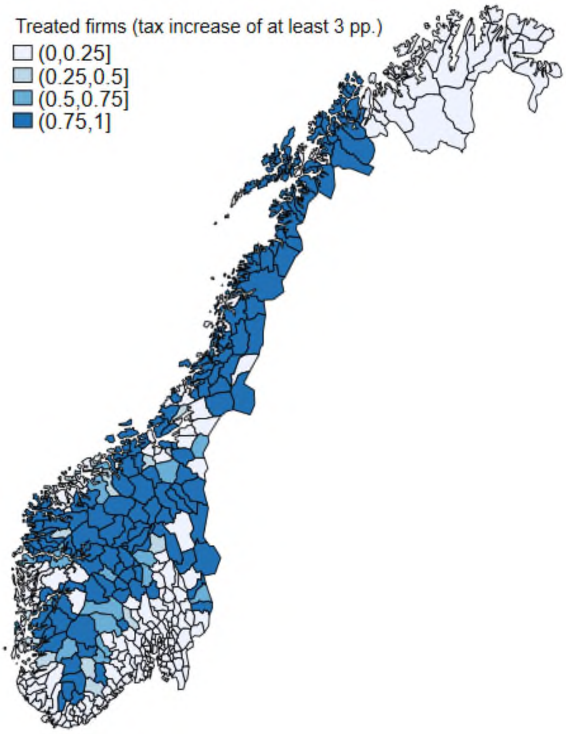
Notes: The table presents descriptive statistics for four groups: treated and control firms, each further divided into medium-sized and large firms. Firms are classified into treated and control groups based on whether their average payroll tax rate is predicted to increase by at least three percentage points (treated) or by less than three percentage points (control) between 2003 and 2007. Firm size classification is based on whether their 2003 wage bills were above or below the median of 5,328,000 NOK (approximately 752,500 USD). Panel A shows descriptive statistics for the full sample of 11,868 firms with a wage bill exceeding 3 million NOK (423,729 USD) in 2003. All variables and sample sizes are measured in 2003, and means are weighted by the number of workers (full-time equivalents) in the firm in 2003. Panel B presents statistics on R&D activities for a subset of 2,290 firms included in the 2003 R&D survey. R&D investments are total annual investments in 1,000 USD (using the exchange rate for 2003; 1 USD = 7.08 NOK). *Data sources* : Norwegian register data and R&D survey made available by Statistics Norway.

FIGURE A.1: Geographical Distribution of Payroll Tax Zones and Treated Firms

A. Payroll Tax Zones, 2003

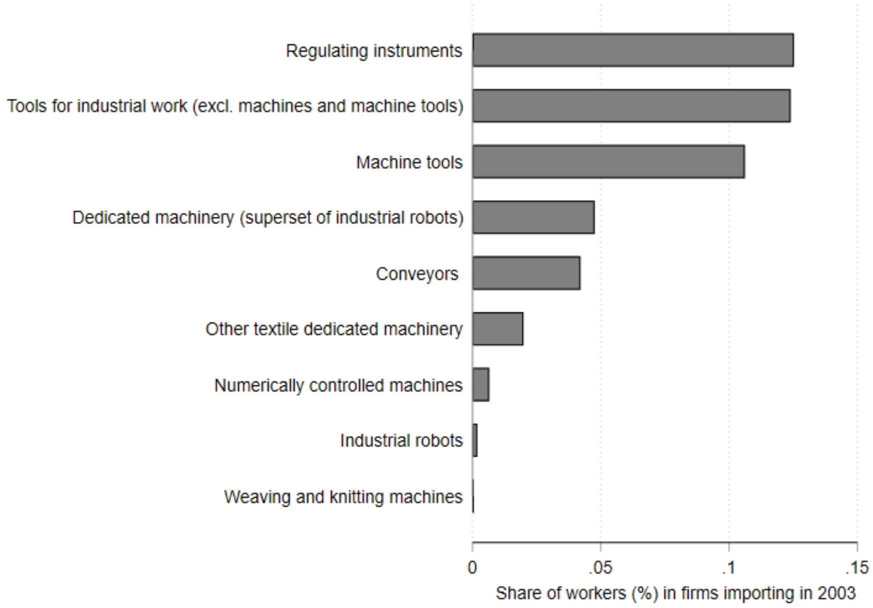


B. Share of Treated Firms



Notes: Panel A shows the geographical distribution of the five tax zones in Norway in the pre-reform year 2003. Panel B shows the geographical distribution of treated firms. Firms are defined as treated if their average payroll tax rate is predicted to increase by at least three percentage points between 2003 and 2007.
Data sources : The Norwegian Tax Authorities.

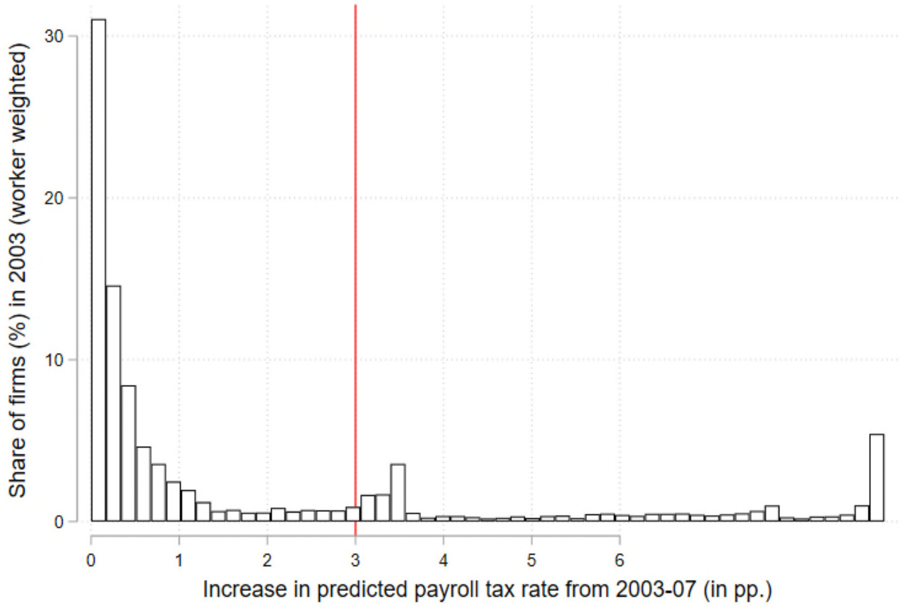
FIGURE A.2: Import of Different Types of Automation Goods in 2003



Notes: This figure shows the distribution of workers across firms importing different types of automation goods in 2003.

Data sources : Norwegian register data and customs data made available by Statistics Norway.

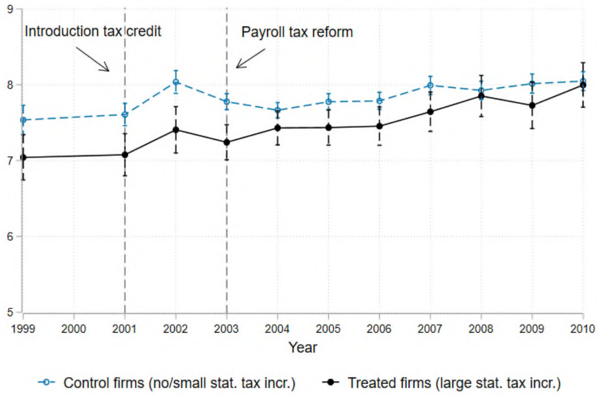
FIGURE A.3: Predicted Increase in Payroll Tax Rate between 2003 and 2007



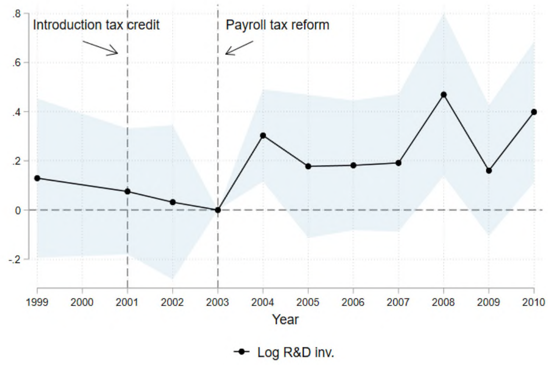
Notes: The figure shows the distribution of workers (in 2003) across firms experiencing different predicted increases in payroll tax rate between 2003 and 2007. At each firm, we compute the predicted increase based on its 2003 worker composition and the tax zone-specific increase in statutory payroll tax rate from 2003 to 2007; see equations (1) and (2). Firms are defined as treated if their average payroll tax rate is predicted to increase by at least three percentage points between 2003 and 2007 (indicated by a red vertical line), and firms with a smaller predicted increase are defined as control firms.
Data sources: Norwegian register data made available by Statistics Norway.

FIGURE A.4: R&D Investments and Tax Credit Receipt in Large Treated and Control Firms over Time

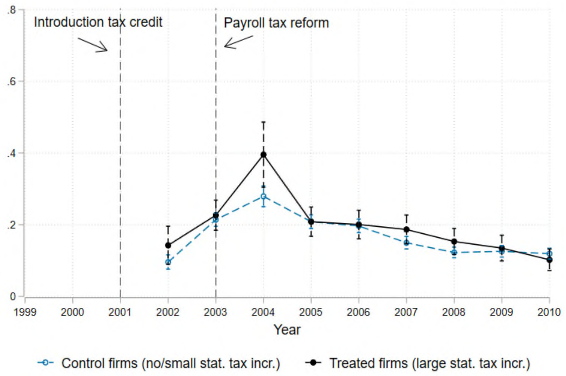
A. Log R&D Investments (Raw Means)



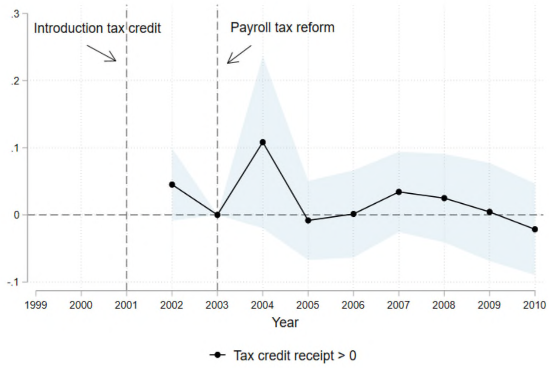
B. Log R&D Investments (DID estimates)



C. Tax Credit Receipt (Raw Means)



D. Tax Credit Receipt (DID estimates)



Notes: This figure presents the raw means (panels A and C) and the event-study estimates based on equation (4) (panels B and D), comparing outcomes at large treated vs. control firms over time. Panels A and B show results for log R&D investments, and Panels C and D for an indicator variable that equals 1 if the firm received tax credits for R&D projects. Raw means for 2003 are normalized to zero. Confidence intervals (blue shaded areas) are shown at the 95% significance level. Both raw means and DID estimates are weighted by the firm's 2003 number of workers (full-time equivalents). The vertical lines indicate the year in which the two reforms took effect: 2001 for the tax credit scheme and 2003 for the payroll tax reform.

Data sources: Norwegian register data and the R&D survey made available by Statistics Norway.

Appendix B: Proofs

B.1 Labor Costs and Automation

The first-order conditions for K, L, and θ are:

$$r = \left[\theta^{\frac{1}{\delta}}K^{\frac{\delta-1}{\delta}} + \left(\int_{\theta}^{1}\psi(x)^{\delta-1}dx\right)^{\frac{1}{\delta}}L^{\frac{\delta-1}{\delta}}\right]^{\frac{1}{\delta-1}}\theta^{\frac{1}{\delta}}K^{-\frac{1}{\delta}}$$
$$= Y^{\frac{1}{\delta}}\theta^{\frac{1}{\delta}}K^{-\frac{1}{\delta}}$$

$$w(1+\tau) = \left[\theta^{\frac{1}{\delta}}K^{\frac{\delta-1}{\delta}} + \left(\int_{\theta}^{1}\psi(x)^{\delta-1}dx\right)^{\frac{1}{\delta}}L^{\frac{\delta-1}{\delta}}\right]^{\frac{1}{\delta-1}}\left(\int_{\theta}^{1}\psi(x)^{\delta-1}dx\right)^{\frac{1}{\delta}}L^{-\frac{1}{\delta}}$$
$$= Y^{\frac{1}{\delta}}\left(\int_{\theta}^{1}\psi(x)^{\delta-1}dx\right)^{\frac{1}{\delta}}L^{-\frac{1}{\delta}}$$

$$\theta^{\frac{1-\delta}{\delta}}K^{\frac{\delta-1}{\delta}} = \left(\int_{\theta}^{1}\psi(x)^{\delta-1}dx\right)^{\frac{1-\delta}{\delta}}\psi(\theta)^{\delta-1}L^{\frac{\delta-1}{\delta}}$$
$$\Rightarrow \psi(\theta) = \left[\frac{K}{L}\frac{\int_{\theta}^{1}\psi(x)^{\delta-1}dx}{\theta}\right]^{\frac{1}{\delta}} \qquad (1)$$

Denote $s^K = \frac{rK}{Y}$ and $s^L = \frac{w(1+\tau)L}{Y}$, and we know $s^K + s^L = 1$. Substituting s^K and s^L into equation (1), we have:

$$\left(\frac{1}{\theta} + \frac{\psi(\theta)^{\delta-1}}{\int_{\theta}^{1}\psi(x)^{\delta-1}dx}\right)s^K = \frac{\psi(\theta)^{\delta-1}}{\int_{\theta}^{1}\psi(x)^{\delta-1}dx} \qquad (2)$$

Taking the log and differentiating the first-order conditions with respect to K and L, we have:

$$dLogr = \frac{1}{\delta}dlogY - \frac{1}{\delta}dlogK + \frac{1}{\delta}\frac{1}{\theta}d\theta \qquad (3)$$

$$dLogw(1+\tau) = \frac{1}{\delta}dlogY - \frac{1}{\delta}dlogL - \frac{1}{\delta}\frac{\psi(\theta)^{\delta-1}}{\int_{\theta}^{1}\psi(x)^{\delta-1}dx}d\theta \qquad (4)$$

Taking the log and differentiating the production function, we have:

$$dLogY = \theta^{\frac{1}{\delta}}\left(\frac{K}{Y}\right)^{\frac{\delta-1}{\delta}} dLogK + \left(\int_{\theta}^{1}\psi(x)^{\delta-1}dx\right)^{\frac{1}{\delta}}\left(\frac{L}{Y}\right)^{\frac{\delta-1}{\delta}} dLogL$$
$$+\frac{1}{\delta-1}Y^{\frac{1-\delta}{\delta}}\left[\theta^{\frac{1-\delta}{\delta}}K^{\frac{\delta-1}{\delta}} - \left(\int_{\theta}^{1}\psi(x)^{\delta-1}dx\right)^{\frac{1-\delta}{\delta}}\psi(\theta)^{\delta-1}L^{\frac{\delta-1}{\delta}}\right]d\theta$$
$$= s^{K}dLogK + s^{L}dLogL \qquad (5)$$

where the second equation comes from equation (2). Combining equations (4) and (5), we have:

$$dLogw(1+\tau) = \frac{1}{\delta}s^{K}(dLogK - dLogL) - \frac{1}{\delta}\frac{\psi(\theta)^{\delta-1}}{\int_{\theta}^{1}\psi(x)^{\delta-1}dx}d\theta \qquad (6)$$

Taking the log and differentiating equation (1), we have:

$$\frac{\psi'(\theta)}{\psi(\theta)}d\theta = \frac{1}{\delta}(dLogK - dLogL) - \frac{1}{\delta}\left(\frac{1}{\theta} + \frac{\psi(\theta)^{\delta-1}}{\int_{\theta}^{1}\psi(x)^{\delta-1}dx}\right)d\theta \qquad (7)$$

Combining equations (6) and (7), we have:

$$\frac{\psi'(\theta)}{\psi(\theta)}d\theta = \frac{1}{s^{K}}dLogw(1+\tau) + \frac{1}{\delta s^{K}}\frac{\psi(\theta)^{\delta-1}}{\int_{\theta}^{1}\psi(x)^{\delta-1}dx}d\theta - \frac{1}{\delta}\left(\frac{1}{\theta} + \frac{\psi(\theta)^{\delta-1}}{\int_{\theta}^{1}\psi(x)^{\delta-1}dx}\right)d\theta$$
$$= \frac{1}{s^{K}}dLogw(1+\tau)$$
$$\Longrightarrow \frac{d\theta}{dLogw(1+\tau)} = \frac{\psi(\theta)}{s^{K}\psi'(\theta)} > 0$$

where the second equation comes from equation (2). This expression corresponds to equation (7) in the main text.

B.2 Labor Coss and the Demand for Labor

Taking the log and differentiating the capital supply function, we get $dLogK = \gamma dLogr$. Combining this expression with equation (3) to eliminate $dLogr$, and using equation (5) to eliminate $dLogY$, we can express $dLogK$ as a function of $dLogL$ and $d\theta$:

$$dLogK = \frac{\gamma(1-s^{K})}{\delta+\gamma(1-s^{K})}dLogL + \frac{\gamma}{\delta+\gamma(1-s^{K})}\frac{1}{\theta}d\theta \qquad (8)$$

Combining equation (8) with equation (6) to eliminate $dLogK$, we obtain:

$$dLogL = -\frac{\delta+\gamma(1-s^K)}{s^K}dLogw(1+\tau) - \frac{1}{s^K}\frac{\psi(\theta)^{\delta-1}}{\int_\theta^1 \psi(x)^{\delta-1}dx}d\theta + \frac{\gamma}{\delta}\left[\frac{1}{\theta} - \frac{\psi(\theta)^{\delta-1}}{\int_\theta^1 \psi(x)^{\delta-1}dx}\frac{1-s^K}{s^K}\right]d\theta$$

$$= -\frac{\delta+\gamma(1-s^K)}{s^K}dLogw(1+\tau) - \frac{1}{s^K}\frac{\psi(\theta)^{\delta-1}}{\int_\theta^1 \psi(x)^{\delta-1}dx}d\theta \qquad (9)$$

where the second equation comes from equation (2). This expression corresponds to equation (8) in the main text.

B.3 Labor Costs and Labor Productivity

Combining equations (5), (8), and (9), we have:

$$dLog\frac{Y}{L} = dLogY - dLogL = s^K(dLogK - dLogL)$$

$$= \delta dLogw(1+\tau) + \frac{\psi(\theta)^{\delta-1}}{\int_\theta^1 \psi(x)^{\delta-1}dx}d\theta \qquad (10)$$

This expression corresponds to equation (9) in the main text.

B.4 Labor Costs and the Labor Share

Taking the log and differentiating $s^L = \left(\int_\theta^1 \psi(x)^{\delta-1}dx\right)^{\frac{1}{\delta}}\left(\frac{L}{Y}\right)^{\frac{\delta-1}{\delta}}$, we have:

$$dLogs^L = -\frac{1}{\delta}\frac{\psi(\theta)^{\delta-1}}{\int_\theta^1 \psi(x)^{\delta-1}dx}d\theta + \frac{1-\delta}{\delta}dLog\frac{Y}{L}$$

$$= -\frac{1}{\delta}\frac{\psi(\theta)^{\delta-1}}{\int_\theta^1 \psi(x)^{\delta-1}dx}d\theta + (1-\delta)dLogw(1+\tau) + \frac{1-\delta}{\delta}\frac{\psi(\theta)^{\delta-1}}{\int_\theta^1 \psi(x)^{\delta-1}dx}d\theta$$

$$= (1-\delta)dLogw(1+\tau) - \frac{\psi(\theta)^{\delta-1}}{\int_\theta^1 \psi(x)^{\delta-1}dx}d\theta$$

where the second equation comes from plugging in the expression of $dLog\frac{Y}{L}$ in equation (10). This expression corresponds to equation (10) in the main text.