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WORKFORCE AGING, PENSION REFORMS AND FIRM OUTCOMES

by Francesca Carta*, Francesco D'Amuri* and Till von Wachter♦

Abstract

Raising statutory retirement ages has been a popular policy to increase the labor supply of older workers in the face of population aging. In this paper, we quantify the effect of a sharp and unexpected increase in retirement ages on firms' input mix and economic outcomes using Italian administrative and survey data on employment, wages, value added and capital. Exploiting information on lifetime pension contributions for the universe of employees, we are able to quantify the extra number of older workers employed by each firm as a result of the reform. We find that a 10 per cent increase in older workers implies a rise in employment of young and middle-aged workers of 1.8 per cent and 1.3 per cent, respectively. Total labor costs and value added increase broadly in line with employment, with little impact on labor productivity and unit labor costs. These results suggest older workers are valuable to employers and that pension reforms postponing retirement can remove a constraint rather than place a burden on firms.

JEL Classification: H55, J24, J26.
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Contents

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1 Introduction

The world is aging at a fast rate and by 2030 34 countries will be "super aged", with a share of 65+ year-olds higher than 20% of the total population (Moody's Investor Service, 2010). Germany, Japan and Italy have already met this definition.[1] This shift in the age structure of the population will tend to lower labor force participation and to increase the dependent population, with potential negative consequences for public pension programs and economic growth (Attanasio et al., 2007; Hansen, 1939; Storesletten, 2000; Summers, 2013).

Against this background, in the last decades governments have tried to increase the labor force participation of older individuals, often by raising the statutory retirement age (OECD, 2015). A much discussed and studied potential side-effect of these policies is that older workers may crowd out younger cohorts in the labor market (e.g., Gruber and Wise (2010); Maestas et al. (2016)). Much less is known about the impact of these policies on the economic outcomes and choices of businesses. On the one hand, larger presence of older workers may hamper firms' productivity and future growth if older workers are less innovative or less willing to take risks than younger ones (e.g., Engbom (2019)). On the other hand, older workers have substantial job experience,[2] and an increasing number of studies suggests that departures of senior colleagues may be detrimental to co-worker productivity (e.g., Jaeger and Heining (2020), Sauvagnat and Schivardi (Sauvagnat and Schivardi)). Moreover, the aging of the labor force has been associated with increases of productivity-enhancing automation at the industry level (Acemoglu and Restrepo (2018)), and hence firms may benefit from increased employment of experienced older workers.

This paper investigates these issues by estimating the causal effects of an exogenous increase in the share of older workers on firms' input levels, wages, value added, capital, and labor productivity. We exploit a sharp and unexpected pension reform entering into force in Italy in 2012 and use unique matched employer-employee and firm balance-sheet data to study its effects. A key feature of our data is the availability of complete pension contribution histories for all workers in our sample of firms. This allows us to calculate for each employer how many of its older employees experienced an unexpected rise in retirement age due to the unanticipated reform. To obtain complete balance sheet information and to ensure a precise measure of this shock, we focus on firms with at least 50 employees at baseline.

Based on these data, our analysis proceeds in four steps. We begin by showing that, in our setting, most older workers retire as soon as they are eligible for a public pension, such that the pension reform led to unanticipated increases in the number of older employees for

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[2] The canonical human capital model predicts that human capital increases over the life cycle (e.g., Becker (1964); Ben-Porath (1967)), and a large number of empirical studies estimate that skills increase with age, be it general skills (e.g., Bowlus and Robinson (2012)) or skills that are specific to industry, occupation, or employer (e.g., Gathmann and Schönberg (2010); Neal (1995); Parent (2000); Poletaev and Robinson (2008); Topel (1990)).

participating employers. We instrument the change in employment due to older workers with the unexpectedly legislated change in the share of older workers eligible to retire. To benchmark our results to the literature, we then study the impact of such unexpected rise in the share of older workers on hiring and separations of younger and middle aged workers. Our main results consist in the analysis of the effect of older workers' employment on a range of firm economic outcomes, including value added, investment, and labor costs. Finally, while our main results pertain to mid-size to larger firms in the manufacturing and services sector, we extend our analysis to the universe of firms of all sizes and in all sectors of the economy, except agriculture. For this large dataset we don't have the full information on individual working histories necessary to simulate pension eligibility, and so we use it for robustness checks only.

The paper has three key findings. First, we find that an exogenous 10% increase in the number of older workers implies a 1.8% increase in the number of young workers, and a 1.3% increase for middle aged, sustained over three years. Hence, older and younger workers seem to be complements in the firms we study. Second, while total labor costs and value added also increase, a key finding is that this occurs proportional to employment, i.e., labor costs per worker and value added per worker are unaffected. Therefore, the reform led to an expansion in output and employment in affected firms at constant average labor cost and average labor productivity. Finally, we do not detect any significant effect of an increase in the number of older workers on wages. While this may be because the Italian institutional setting features rather rigid wages, this would only enhance potential negative consequences if older workers were to represent a burden to the firm. Since our identification strategy relies on the exogenous variation of employment of older (55+) employees across otherwise identical firms, it does not allow us to detect economy-wide changes in the wage. To circumvent this problem, we analyzed the change employment and mean wages by age over time. While this shows the reform led to clear shifts in employment rates among older workers, we find no reduction in wages for those nearing retirement.

Our results provide evidence for the presence of complementarity between workers of different age classes. The fact that employment and value added increase at constant labor productivity suggests that firms are able to absorb older workers without difficulties, at least in the short term. These findings are hard to reconcile with the notion that additional older workers are a burden on firms. Instead, they appear to be more consistent with the view that older workers have skills and other attributes coveted by firms that may be difficult to replace in the labour market, as suggested by a large empirical literature on skill-accumulation in labor economics, and in line with recent related work on frictions in hiring (Jaeger and Heining, 2020). Certainly, it does not appear that an increase in older workers at the firm level is a barrier to investment or lowers labor productivity, consistent with findings in Acemoglu and Restrepo (2018) that older workers in the US appear to be complements to technologies and automation.

This paper is related to several strands of prior literature. Chiefly, our paper contributes to a small but growing number of microeconomic studies of the effect of older workers' employment on firms outcomes. A key value added of our work to this emerging literature is to study the causal effect of firm-specific quasi-experimental increases in employment of older workers on a range of firm-level economic outcomes. We thereby complement panel-based estimates that do not find a negative relationship between firm-level older workers' employment changes and firm outcomes, and cross-sectional estimates that do.[3]

A related macroeconomic literature studying the relationship between older workers' employment

[3]Cross sectional analyses find that the presence of older workers tends to be negatively associated with estimates of firm productivity (Haltiwanger et al., 1999; Lallemand and Rycx, 2009; Mahlberg et al., 2009). Nevertheless, such a negative relationship is not found in studies using panel data (Daveri and Maliranta, 2007; Göbel and Zwick, 2012; Malmberg et al., 2008; Mahlberg et al., 2013) or in more structural approaches (Dostie, 2011). See Table A1 for a schematic review of the literature on the effects of aging workforce on firm outcomes.

and economic outcomes at the country, state, and industry level provides important findings complementary to ours. Acemoglu and Restrepo (2018) find that, in industries with more opportunities for automation, an increasing share of older workers leads to productivity increases. While in their model it is the relative decline in middle-aged workers that triggers automation, the increasing share of highly experienced older workers can help support this process. Engbom (2019) finds that labor force aging in the last 30 years among US states lowered worker and firm dynamism with ultimately negative effects on economic growth.[4] While our approach is designed to exclude confounding factors that are more difficult to control for in a macroeconomic setting, we focus on at most three years after the reform and cannot capture general equilibrium effects. Yet, our results underscore that frictions in the hiring of older workers, likely explained by availability of pension benefits and lack of worker mobility, can be costly for employers.

Our findings are consistent with a large empirical literature in labor economics that has documented increasing age-experience profiles in skills that are both general and specific to the occupation, industry, or employer. Recently, an increasing number of studies have documented the effect of a loss of co-workers, and in particular of a senior team leader, on worker productivity. Jaeger and Heining (2020), Isen (2013) and Sauvagnat and Schivardi (Sauvagnat and Schivardi) investigate the effect of death of a co-worker on worker and firm outcomes. Other papers study death of inventors (Jaravel et al., 2018), primary investigators (Azoulay et al., 2010), or the departure of professors (Waldinger, 2012). In contrast to these papers, we analyze the effect of an increase, not a reduction, of senior colleagues on worker and business level outcomes.[5] Our approach extends this literature since we focus on firms' outcomes. We are aided by the fact that we study the effect of a change in employment of a group of workers, not a single individual, and hence may be more able to detect firm level impacts. Other papers using worker firm-level changes in employment typically focus on worker outcomes, not firm outcomes, such as studies of the effect of job losses during group or mass layoffs. Another related paper focusing on worker outcomes is Bianchi et al. (2020), who study the effect of the same reform we analyze on careers within firm, and find that the rise in older workers leads to a reduction in wage growth for workers not in retirement age. While our methodologies differ, their results are consistent with friction preventing the hiring of older workers, such that a retirement would lead to an internal promotion. In this context, our findings suggest that these freshly promoted workers are not as valuable to the firm as the older workers they replace.

Our paper is also related to a substantial literature studying the effect of older workers' employment on younger workers' job opportunities at the macro and micro level. Studies exploiting macroeconomic variation typically do not find a negative correlation between older and younger workers' employment.[6] Recent microeconomic studies based on pension reforms find mixed evidence of the effect of delaying older workers retirement on younger workers' employment outcomes. For example, Martins et al. (2009) find negative effects for women but not for men in Portugal. In the Netherlands, Hut (2019) finds a negative effect of delay in retirement on younger workers employment concentrated in cash-constrained firms. Studying the same reform as we do, but focusing on smaller to mid-size employers, Boeri et al. (2017) find a negative effect of a firm's growth in the number of older workers on employment of younger workers. After an extensive robustness analysis, we conclude that the difference in results is

[4] Feyrer (2007) uses a large panel of countries and shows that increases in the proportion of workers aged 40-49 are associated with productivity growth, while those in younger (15-39 year olds) and older (50-59 and 60+) cohorts have negative effects.

[5] In another analysis of a positive employment shock, Doran et al. (2015) find that firms that win an H-1B visa in a lottery and hire an H-1B worker moderately reduce the employment of other workers at the firm.

[6] Studies working at the macro level do not detect any negative trade-off between the employment rates of older and younger cohorts (Gruber and Wise, 2010; Maestas et al., 2016; Tommasino and Zizza, 2015), that - if any - is restricted to periods of economic downturns (Bertoni and Brunello, Bertoni and Brunello); some negative effects are found on young workers' occupations and wages (Mohnen, 2019).

likely to be due to the fact that our main measure of the shock relates the number of excess older workers' to total employment of the firm rather than to the pre-existing stock of older workers, a measure intended to better capture the economic impact of the reform on businesses.

The rest of the paper is organized as follows. Section 2 briefly reviews predictions from theory; Section 3 presents the data, and Section 4 describes the Italian pension reform that we exploit in the empirical analysis. Sections 5 and 6 discuss the identification strategy and present main (static and dynamic) results. Section 7 provides further robustness checks. Section 8 concludes.

2 Effects of pension reforms on firm outcomes

This section briefly reviews the predictions for the effect of a pension-induced reduction in the retirement rate of older workers on the main outcomes of interest: the employment of older and younger workers, wages, investment, value added, labor productivity, and profitability of firms. We begin with a frictionless, competitive, benchmark and then move to more realistic scenarios frequently considered in the context of older workers, such as rigid wages and high firing costs. We conclude that although theories based on generic production functions are very flexible, a model in which older workers have firm-specific or other hard-to-hire-for skills is a good candidate to explain our findings.

The empirical literature has found, and we confirm, that pension reforms have a strong effect on older workers' employment choices due to financial incentives and social norms, among others.[7] An increase in the statutory retirement age thus reduces the quit rate of older workers. In the following discussion we assume this is an exogenous shock to the firm. In the empirical analysis, we will turn to an instrumental variable strategy.

Competitive Case

Assume as a benchmark case that older workers' skills are available on the market at going wages, that there are no firm-specific skills or firing costs, and that labor markets are perfectly competitive. Hence, in every period firms can freely choose the age composition of their workforce. The production function combines capital and labor, where labor is a composite of old and young workers. In this case, in the aftermath of an increase in the statutory retirement age, wages of older workers fall and they remain fully employed. This increase in the employment of older workers affects utilization and prices of younger workers and capital depending on whether they are substitutes or complements in production with older workers. Firms' profits are unaffected since factor prices equal their marginal products. In typical cases, there will be an increase in total value added.[8] Finally, under standard assumptions of decreasing or constant returns to scale, average labour productivity would be expected to fall.

Case of Wage Rigidities and Firing Costs

In the presence of implicit or explicit long-term contracts and high seniority, often wages are deemed downwardly rigid and the actual or reputational costs of firing older employees can be high. In this scenario, raising the statutory retirement age increases the stock of older workers employed at the firm without a corresponding reduction in wages, and the firm will

[7] E.g., Cribb et al. (2016); Lalive et al. (2017); Manoli and Weber (2016); Mastrobuoni (2009); Staubli and Zweimüller (2013).

[8] Unless, for example, the reduction in the marginal product of other inputs offsets the increase in production from additional older workers.

optimize profits by adjusting the level of other inputs.[9] This adjustment again depends on the degree of complementarity of these inputs with older workers and on the diminishing marginal product of aggregate labor. When complementarities prevail over the reduction in the marginal product of labor, the firm's employment of younger workers goes up and total firm size and overall production increase.[10] Only if older and younger workers are perfect substitutes the firm reduces employment of younger workers and does not change the overall level of employment and production. The effect on profits is ambiguous, but is likely to be negative if firms were at an optimum before the reform.[11] Similarly, from an optimum, labor costs per worker would be expected to increase, and average labor productivity would be expected to fall.

Case of Specific Skills

It may be that older workers' skills are scarce in the labor market, for example if skills are firm-specific or if older workers are hard to replace because of frictions.[12] An increasing number of studies reports evidence that higher-tenured workers are indeed hard to replace (e.g., Azoulay et al. (2010); Jaeger and Heining (2020); Isen (2013); Sauvagnat and Schivardi (Sauvagnat and Schivardi); Waldinger (2012)). The retirement rate represents the depreciation rate of this stock of hard-to-replace human capital. By raising the amount of high-skilled older workers and reducing the short-run costs or constraint of obtaining these skills, an increase in the statutory retirement age thus represents a gain for the firm, rather than an inconvenience or a cost. This positive shock leads to an increase in total employment, value added, and profits. The employment of younger workers increases, whereas the response in capital depends on the degree of complementarity with the labor input. Output per worker will not decrease, and may increase depending on the degree of complementarity between workers of different age.[13]

These initial adjustment patterns could change in the long run. In the context of firm-specific training, consider a turnover model in which young/inexperienced workers are hired to replace old/experienced workers who retire in the next period. The steady state property of the model implies a negative trade-off between young and old workers: the number of young workers hired needs to be equal to the number of old workers who retire.[14] In this case, a permanent reduction in the retirement rate would tend to lower the need to hire and train younger workers. However, in the presence of high turnover costs and high quit rates, the firm may still find it

[9] If firms face small or moderate adjustment costs, they can restore the optimum by firing older workers, leaving unchanged other input quantities with no effect on value added. If young and old workers are perfect substitutes, the firm could instead reduce hiring or increase firing of younger workers as well.

[10] If the production function has constant returns to scale, only the presence of complementarities between young and old workers drives the effects on other inputs of an increased number of old employees.

[11] Applying the Envelope theorem, the effect on firm's profit depends on the difference between the marginal product of older workers (given the other input quantities at the new optimal level) and older workers' wages. Diminishing marginal productivity would imply a negative effect, while complementarity with other inputs can lead to a positive effect. The presence of deferred compensation contracts for older workers would reinforce the negative effect of the pension reform on profits.

[12] Human capital theory predicts that older workers have on average higher skills (Becker, 1962; Ben-Porath, 1967; Lazear, 2009); such result has been confirmed by a large empirical literature in labor economics analyzing general (e.g., Bowlus and Robinson (2012)), industry-specific (e.g., Neal (1995)), occupation-specific (e.g., Parent (2000); Poletaev and Robinson (2008); Gathmann and Schönberg (2010)), or firm-specific skills (e.g, Topel (1990)).

[13] General hiring/search costs on the employer's side (recruiting, opening of a vacancy, etc.) could be present for all age classes. Retaining older, high-tenured workers would cut general recruitment costs with positive effects on profits. However, it seems implausible that this would lead to an increase in costly hiring of younger workers and an expansion in production if hiring costs had not been particularly high for older workers.

[14] A firm could try to induce older workers to work longer through offering higher wages. Once eligible for a pension benefit, this could be very costly, due to the presence increasing marginal tax rates as pension constitutes taxable income. In steady state the cost of training a younger worker will equate the cost of retaining an older worker.

optimal to expand total employment in response to the lower retirement rate. In this case, the rise in firm's total scale can lead to a larger number of younger workers and an expansion in production over the long run as well.

3 Data

Analyzing the effects of an increase in the number of older workers on firm outcomes is demanding in terms of data; in particular, we need information on the age-structure of the workforce of each employer, typically not available in survey or administrative firm-level data. We also need firm-level economic outcomes, which is typically not available in worker-level data. In addition, for each employee we need their full earnings and work history to infer pension eligibility. For the purpose of our analysis, we use a unique data set that matches three different sources of data. The first one is the Bank of Italy's Survey on Industrial and Services firms (INVIND).[15] It is a panel of 4000 manufacturing and services firms in the private non financial sector with 20+ employees (representative of 70% of total sales in the Italian economy). The second source of data is the Social Security administrative data set, provided by INPS – the Italian National Social Security Institute –, with full working histories, wages and main job-related socio-demographic characteristics of all workers employed at least one day at INVIND firms during the 2005-2015 time interval. In particular, all the needed information is available in order to retrieve the exact year in which the individual is eligible for a public pension (that is, gender, age and years of paid social security contributions); for a subset of workers, it is also possible to observe when the individual actually claims the public pension.[16] Third, we use CEBI (Centrale dei Bilanci), which contains full balance sheet information for each firm in every year (total labor costs and valued added, capital).

We restrict the analysis to the years 2010-2014. The far reaching pension reform used as an exogenous shifter for older workers' labor supply entered into force in January 2012. We are able to follow our firms for two years before and two years after the reform. Another pension reform took place in 2008 that could potentially confound the results, while a major labor market reform, coupled with hiring incentives, was legislated in 2015 (Sestito and Viviano, 2018).

We restrict the analysis to firms that employed at least 50 employees in the year they first appeared in the sample; we implement this restriction for two reasons: i) balance sheet information can be patchy and variables can show very volatile dynamics in smaller firms, ii) since the INVIND survey covers 20+ firms only, there could be non random attrition of shrinking firms as they cross the 20 employees threshold from above and of course such phenomenon is more likely to happen in smaller firms (D'Aurizio and Papadia, 2019). Anyway, we statistically test whether the reform we study had an impact on firm exit and entry into the sample. Finally, we restrict the data to firms sampled in each of the five years and do not have missing values on variables such as capital, labor costs and value added. Our final sample is a balanced panel of 1,025 firms/year for a total of 5,125 observations. Descriptive statistics for the main variables are reported in Table A2.[17]

In a robustness check, we also replicate the main analysis on a data set covering the whole population of Italian firms who paid social security contributions for at least one day in a given year between 2010 and 2014 (1.5 million firms). For this large matched employer-employee dataset we do not have the information needed to calculate the minimum age at which individuals

[15] See Bank of Italy (2014) for a description of this data source.

[16] This information is only available for workers born in 24 birth dates a year.

[17] All estimates presented in the paper are unweighted, but the inclusion of survey weights would not alter the results in any way. We also carried out the analysis on a balanced or unbalanced sample for most outcomes and got similar results. Results for the weighted regressions are not reported here but are available upon request.

can claim a public pension. For this reason and the reasons mentioned above we use it mainly as a robustness check.

4 The Italian pension system and the 2011 reform

In the last decades the Italian pension system has been revised through a long term reform process aimed at improving its financial sustainability. In our empirical analysis we take advantage of the pension reform legislated at the end of 2011 and that unexpectedly increased the minimum legal requirements for public pension eligibility (Law 214/2011, known as "Fornero Reform"). The reform passed at the end of 2011 (December 22) during the sovereign debt crisis, and was effective from January 1, 2012. The reform was completely unexpected, as confirmed by the incidence over time of google searches for "pension reform" that had an all-time peak just in December 2011 (Figure A1 of the Appendix).

As in many OECD countries, the Italian pension system is characterized by a large first pillar consisting of public pension funds and by almost negligible second and third pillars (respectively, compulsory and voluntary[18] pension funds). Two types of work-related pension benefits are available and give access to full retirement: old age and seniority schemes. Eligibility for the first one is mainly based on workers' age. For the second, it mainly depends on the number of accrued years of social security contribution.

The substantial changes in the eligibility rules introduced by the reform for both the *seniority* and the *old age* pensions are summarized in Figure 1. Such changes implied an overnight increase in the average Minimum Retirement Age (MRA) of about 3 years for individuals aged 55 and more. We provide full details of these changes in Section A.1 of the Appendix. The new rules in place since 2012 allowed workers who were already eligible for a public pension when the bill passed to retire under the pre-reform rules, without losing their eligibility.

4.1 Simulation of pension eligibility and Minimum Retirement Age

The sudden pension reform led to unexpected changes in public pension eligibility and a reduction in the retirement rate. Workers were affected differently depending on their age, gender and years of accrued social security contributions. The policy change also increased the number of older workers more in some firms than others, partly because of differences in the number of older workers near retirement age. In addition, given eligibility can also derive from seniority and gender, firms experienced differential increases in older workers' employment even for a given age structure.

In order to reconstruct the share of eligible workers at the firm level and its unexpected changes over time we follow several steps. First, we need to recover the minimum age at which an individual has access to pension benefits. We call it Minimum Retirement Age (MRA) – the minimum between the retirement age for old age and seniority pension (see Section 4 and Figure 2, bottom panel) – and it is computed for all individuals in each year, on the basis of three characteristics (age, gender, number of accrued years of social security contribution) and according to two different sets of pension rules. First, the MRA is computed according

[18] The legislative decree n. 252/2005, implemented in 2007, introduced an automatic enrolment mechanism for voluntary pension funds: if an employee does not make an active choice after a six-month period (counting from January 1, 2007 for old employees and from the hiring date for new employees), the severance payment will automatically be assigned to an occupational pension plan (typically, the industry-wide occupational plan). However, according to Covip (2018), in 2017 less than 30% of the Italian working population has signed a contract with a private pension fund; however, private pension benefits are conditional on the eligibility for a public pension.

to pension rules in place at time t ($MRA_{it}|Law_{t|t}$); second, it is determined on the basis of pension rules known at $t-1$ for time t ($MRA_{it}|Law_{t|t-1}$). Since the MRA is determined also by the number of accrued years of social security contribution at the end of the individual working career, we assume that individuals in our sample will accumulate years of contribution continuously from the year of observation onward.

As a second step, we define workers' pension eligibility at t according to the pension rules in place at time t, and the expected eligibility at time t based on the rules in place at time $t-1$:

$$ELIG_{it}|Law_{t|t} = \begin{cases} 1 & if\ age_{it} \geq MRA_{it}|Law_{t|t}, \\ 0 & otherwise. \end{cases} \tag{1}$$

and

$$ELIG_{it}|Law_{t|t-1} = \begin{cases} 1 & if\ age_{it} \geq MRA_{it}|Law_{t|t-1}, \\ 0 & otherwise. \end{cases} \tag{2}$$

The dummies $ELIG_{it}|Law_{t|t}$ and $ELIG_{it}|Law_{t|t-1}$ refer, for individual i, to eligibility in t according to the pension rules in place at time t and $t-1$, respectively.

Once we have reconstructed actual and expected eligibility and the MRA at the individual level, we can assess the magnitude of the changes that were introduced by the 2011 pension reform at the aggregate level and across firms.

Based on these definitions, our calculations show that the law had large effects on the average retirement age. In the top panel of Figure 2, the dashed line identifies for each year the share on total private sector employees of workers that in year t were expected to become eligible to retire according to the law in place in year $t-1$, while the solid one refers to the share of individuals who actually became eligible in year t with the legislation in place at the beginning of year t. Any divergence between the two is due to unexpected changes in eligibility criteria between $t-1$ and t. From the graph it is clear that no unexpected changes take place in any year but in 2012 – the first year of implementation of the reform. In that year, the share of workers who were expected to become eligible to retire was equal to 2.0%, and it actually went down to 1.2%. In Figure 2, we also show the expected MRA at t given the law in place in $t-1$ and the actual simulated MRA for workers aged 55 or more; also in this case the pattern is the same, apart from the large unexpected increase in the MRA that takes place in 2012, equal on average to 3 additional years in order to reach eligibility.

Looking at the aggregate level, such changes seem to have had a clear impact on the share of 55+ workers employed in our sample of firms. In Figure 3, we show in dark grey the actual shares of 55+ workers on total employment in our sample, and in light grey the projected evolution of such share based on the pre-2012 trend. While the data points overlap in 2010 and 2011, a wedge opens in 2012 and increases over time. In 2014, the actual share of 55+ workers is slightly below 15 p.p., almost 3 p.p. higher than the level projected according to the pre-2012 trend.

5 Empirical analysis

5.1 First differences OLS

The goal of the analysis is to measure the causal effect of an increase in the employment of older workers on firm outcomes. We start by exploiting the panel structure of our data and estimating the following specification in first differences:

$$\triangle y_{j,t} = \alpha + \beta\left(\frac{OLD_{j,t} - OLD_{j,t-1}}{EMPL_{j,t-1}}\right) + \phi X_{j,2010} + d_{st} + \epsilon_{j,t} \tag{3}$$

where j and t respectively identify firm and year and $y_{j,t}$ is a set of firm outcomes; $\frac{OLD_{j,t}-OLD_{j,t-1}}{EMPL_{j,t-1}}$ is the change in older workers employment (55+ year-old) as a share of firm total employment in $t-1$; d_{st} are sector (manufacturing or services) by year fixed effects and $X_{j,2010}$ are the shares of middle aged (35-54) workers and old (55+) workers on total employment in the initial year of the analysis (2010).

We look at a range of different outcomes at the firm level: (a) net change in the number of workers aged 15-34 and 35-54 (equal to total hiring minus total separations); (b) gross changes in hiring and separations separately by temporary and permanent contracts (c) full time equivalent wage for 15-34, 35-54 and 55+ age classes (d) firm total labor costs, value added, capital, both total and in per worker terms. For changes in employment (a), the dependent variable $\triangle y_{j,t}$ is defined as $\frac{y_{j,t}-y_{j,t-1}}{EMPL_{j,t-1}}$; for variables in ($b$) and ($c$), the dependent variable $\triangle y_{j,t}$ is defined as $\frac{y_{j,t}-y_{j,t-1}}{y_{j,t-1}}$.

We choose to carry out all our estimates in first-differences since in this way we control for time-invariant unobservable characteristics. To also control for firm specific trends, in our main results we also add firm fixed effects f_j to the first differences estimates. Year fixed effects absorb a common non-linear trend.

Even though they control for time invariant unobserved heterogeneity and possible linear firm-specific trends, estimates based on equation 3 may still be biased if net employment variation of older workers is endogenous to firms' demand conditions. First, one would expect that older workers more likely keep on working rather than retire if employed in a booming firm to enjoy higher future wages. Second, booming firms might retain more workers of any age class, invest more, and produce more. This would lead β in equation 3 to be upward biased reflecting, for example, a spurious positive correlation between a rise in older workers' employment and a rise in value added.

In our empirical analysis, we exploit the panel nature of our data to directly assess whether there are pre-existing trends that are correlated with the change in the fraction of older workers around the reform (Section 7.1). Since we do not find evidence of such trends, we believe our OLS models in itself are informative. In addition, in our main estimation strategy we use the exogenous variation introduced by the reform to implement instrumental variable estimates.

5.2 First differences IV

The unexpected change in the minimum retirement age allows us to overcome these endogeneity issues by providing an exogenous shifter in the supply of older workers. This is because in Italy, during this period, pension wealth is maximized when claiming the public pension as soon as eligibility is reached. Hence, most workers claim at the MRA: unexpected changes in the pension rules thus provide exogenous variation in older workers employment in otherwise identical firms.

We test the validity of these assumptions by estimating the probability to claim pension benefits – and of being employed – as a function of the number of years to or from the time in which the individual actually reaches pension eligibility.

We estimate the following individual-level event-study model:

$$Y_{it} = \alpha + \sum_{k \geq -m}^{M} \phi^k D_{it}^k + \psi X_{it} + \epsilon_i \tag{4}$$

where Y is equal to one if the individual i claims a public pension (is employed) at time t,[19] X are individual-level characteristics (age, gender, years of social security contributions),

[19] Here, we adopt the loosest possible definition of employment, defining individuals as employed in year t if

D^k_{it} is an indicator for the k-th period before or after eligibility is reached (from m periods before to M periods after eligibility onset ($k = 0$)). The coefficient ϕ^k captures the change in claiming/employment rate for each k.

In Figure 4 we show the point estimates for ϕ^k from regression 4. The clear discontinuity in the year in which eligibility is reached shows that most individuals claim a public pension as soon as they are entitled to it (top panel) and stop working (bottom panel). Indeed, there is an almost deterministic link between pension eligibility and retirement (confirming the results of Battistin et al. (2009)).

This result is not surprising since for all workers who started working before 1993 (including those directly affected by the reform we study) the public pension is a Defined Benefit plan; the transfer a retiree receives is an approximately fixed percentage of the last ten years' average wage. Once eligibility is reached, postponing the claim results in a negligible increase in the amount of the transfer received (through seniority related wage growth) that does not make up for the forgone transfers. The private pension system plays a minimal role.[20]

5.2.1 First stage

We use the exogenous variation in MRA provided by the reform to implement an instrumental variable (IV) strategy. We use the increase in the share of older workers that was unexpected by the firm as an instrument for the potentially endogenous change in the share of older workers in equation 3. To do so, we need to simulate eligibility for pension benefits for all older workers in a given firm, something that is typically hard to do since it requires knowledge of complete working histories in order to reconstruct the number of years of social security contributions. However, our data allow us to simulate eligibility under the old and the new law.

Once eligibility is simulated at the individual level, we calculate the share of eligible workers losing pension eligibility at the firm level. We focus on year 2012, since it is the only year in which the pension rules changed unexpectedly in the years we study. We show in Figure 5 the distribution of the share of a firm's total workforce of 55+ workers losing eligibility because of the reform we study. In other words, we plot the distribution of our instrumental variable

$$z_{jt} = \frac{ELIG_{j,2012}|Law_{2011} - ELIG_{j,2012}|Law_{2012}}{EMPL_{j,2011}}.$$

The instrument displays a large amount of variation across firms. A non-negligible fraction of firms is unaffected by the policy change (with share zero). Among firms experiencing a reduction in the fraction of workers eligible to retire, the reduction in the fraction eligible is 3 per cent among the total workforce or less.

To get a sense of the variation implied by the instrument, it is useful to decompose it into the share of workers age 55+ employed at the firm in 2011 that lose eligibility, and the share of workers 55+ among a firms' total employment in 2011. Figure 3 shows that the average share of older workers in 2011, the year prior to the reform, was about 10.3%. Hence, for example a 2% (1%) increase in the share among *total employment* for the average firm would imply roughly 20% (10%) of workers age 55+ had their MRA increased by the reform.

Turning to the first stage, we estimate the following regression for years 2011-2012:

$$\frac{OLD_{j,2012} - OLD_{j,2011}}{EMPL_{j,2011}} = \delta + \beta \frac{ELIG_{j,2012}|Law_{2011} - ELIG_{j,2012}|Law_{2012}}{EMPL_{j,2011}}$$

they had worked at least for one day in that year.

[20] In 2015 24.2% of workers were enrolled in private pension funds; private pension benefits are usually small compared to the public ones.

$$+\gamma\frac{ELIG_{j,2012}|Law_{2011}}{EMPL_{j,2011}}+X_{j,2010}+d_s+\epsilon_{j,2012} \quad (5)$$

where $\frac{ELIG_{j,2012}|Law_y}{EMPL_{j,2011}}$ is the fraction of eligible workers in 2012 according to the law in place in year t with $t = 2011, 2012$. We add sector fixed effects d_s and the share of 55+ and 35-54 y.o. workers in 2010 ($X_{j,2010}$) as control variables.

The exclusion restriction implies that, conditional on the control variables, the change in the share of workers who are eligible to retire in 2012, as determined by the unexpected change in the law taking place between 2011 and 2012,[21] changes the fraction of older workers employed at the firm but is not correlated with unobserved firm-level demand shocks. The key identifying assumption is supported by the following: *i)* eligibility is determined by the interaction between pre-determined characteristics of the workers (some of them difficult to observe with precision by firms, such as years of paid social security contributions) and rules that changed significantly and in unexpected ways (see Section 4 and Tables A3 and A4 in the Appendix), *ii)* individuals in our sample retire as soon as they reach eligibility, given the incentives provided by the institutional setting (as discussed in Section 4 and shown in Figure 4).

Table 1 reports the results of our first-stage regression; the main coefficient has the right sign: at the firm level, a one percentage point unexptected decrease in the share of eligible workers is associated to a 0.56 percentage point increase in total employment due to 55+ workers (the estimate is statistically significant at the 1% level). The F-test of excluded instruments equal to 32 signals the instrument has power.

We conduct two additional tests in order to assess the validity of our instrument. First, in Figure A2 of the appendix we report on the X axis - for each quintile of the respective distribution - the averages of the residuals of a regression of the instrument on the controls, and on the Y axis the corresponding averages for a regression of the instrumented variable on the controls. The relationship between the instrumented variable and the instrument is monotonic and quite stable across the firm-level distribution of changes in eligibility. Second, we run a set of placebo estimates in which we regress the instrumented 55+ employment change taking place in 2012 on the cumulative changes of actual 55+ employment taking place between 2010 and 2014. Figure 6 shows that in the two years preceding the reform (2010 and 2011), changes in 55+ employment at the firm level were uncorrelated with the instrumented 55+ employment change taking place in 2012. After 2012, estimated coefficient values remain around one, signalling that the increase in 55+ employment taking place when the reform entered into effect was still visible two years after its inception. This is consistent with the fact that the average delay in MRA implied by the reform for 55+ workers was equal to three years (e.g., see the second panel of Figure 2).

6 Results

Throughout our main empirical analysis, we discuss both our OLS estimates based on panel data and the IV estimates. While the IV results are our preferred estimates, we view the OLS estimates as providing corroborating information for the following reasons: we find no evidence of firm-specific trends either when including firm fixed effects or in our dynamic analysis (Subsection 7.1); in many cases our OLS and IV estimates are qualitatively very similar and are not statistically different from each other; the IV estimates tend to have a higher variance since by design they use much less variation than the panel data.

[21] See Table A3 and the appendix for details of changes in pension legislation.

6.1 Employment and wages

We find that an exogenous increase in employment of older workers at the firm leads to an increase in employment in other age classes as well. This occurs through an increase in hiring and a (somewhat smaller) decrease in separations. The net increase in employment is driven by increases in both fixed-term and permanent positions for younger (15-34) workers and by a rise in permanent positions for the middle-aged (35-54). Finally, we find no clear impact on wages for workers of any age.

We start by looking at the results for *net employment* (Table 2). We find a strong and positive association between variation in 55+ employment and employment of young (15-34 years old) and middle-aged (35-54 years old) workers. These results hold when estimating equation 3 both without and with firm fixed effects, and are nearly identical across these two specifications; results are also very similar when looking at the balanced or unbalanced panel (Column 1-2 and 3-4, respectively), signalling our findings are not affected by sample selection over time.[22]

We also restrict the analysis only to employment changes taking place between the reform year (2012) and the previous one, which allows us to directly compare OLS with IV estimates (bottom panel of Table 2). For 15-34 workers the coefficient estimate remains very similar in 2011-12 for both OLS and IV estimates; for relatively more mature (35-54) workers, point estimates do not move when looking at the single-year first difference OLS, but decrease by a half when considering the corresponding IV results.[23]

Taking the IV estimates as our favorite coefficient estimates, a 1 percentage point increase in total employment due to 55+ workers would imply a 0.5 percentage point increase in the share of younger workers. The implied elasticities between old and youth (middle aged) employment are equal to 0.018 (and 0.013), meaning that a 10% increase in the number of older workers due to the reform would imply a 1.8% (1.3%) increase in the number of young (middle aged) workers.[24]

Tables 3 and 4 analyze more in detail the dynamics behind the net employment changes we find in terms of *hiring and separation margins* and changes in *permanent and fixed term contracts*. The positive employment variation for 15-34 workers is mostly attributable to an increase in the hiring rate (Column 1, Table 3), while separations move little (Column 3). Looking at 35-54 workers, we find both an increase in hiring and a decrease in separations; results are qualitatively similar across specifications, but the IV estimates are not statistically different from zero.

We also find that the contribution of temporary and permanent contracts in explaining the net employment increases differ by age (Table 4). Overall, for 15-34 individuals a substantial share of the increase in net employment occurs via a rise in fixed-term contracts; in contrast, in response to a rise in the share of older workers, workers age 35-54 are substantially more likely to be hired under a permanent contract. The magnitudes of the point estimates of the OLS specifications and IV model vary somewhat, especially for the middle aged, but the qualitative findings are similar across specifications.

[22] The positive relationship between firm level-employment changes among 55+ aged workers and of workers aged 15-34 is also apparent in non-parametric plots. We first separately regressed net employment changes among 55+ and 15-34 y.o. on controls. Figure A3 of the Appendix shows, by quintiles of the residuals of 55+ variations, a connected scatterplot of the mean of 55+ and 15-34 variation residuals. A positive monotonic relationship is apparent.

[23] By the formula of a standard Hausman test, $t = (b^{ols} - b^{iv})/\sqrt{\sigma^2_{iv} - \sigma^2_{ols}}$, the difference in the estimates is statistically significant.

[24] The elasticities are obtained by multiplying the coefficient estimate by the inverse of the pre-existing share of the specific age class in total employment. As we saw in Subsection 5.2.1, at the average share of older workers in employment, a 10% increase in the number of older workers would correspond to a rise in 1% of the share of older workers in employment due to the pension reform.

Moving on to *wages*, Table 5 shows the impact of an increase in the share of workers age 55+ on year-on-year changes in Full Time Equivalent (FTE) daily wages.[25] We find that employment growth in the 55+ age class is associated with a decrease in FTE wage growth concentrated in their own age class that is broadly similar across specifications (Column 3). The effect is not statistically different from zero for the IV estimate, our preferred specification. Point estimates are very close to zero and not statistically significant in the other age classes for all specifications.[26]

Increases in employment coupled with no or small wage reductions can be rationalized by the fact that, in the Italian institutional setting, wages tend to be rigid in the short run due to the importance of collectively bargained national contracts setting wages for three years in advance (see Adamopoulou et al. (2016)); moreover, should an increase in employment for any of the three age classes imply an increase in their wages in the whole economy, we would still fail to see them, given the fact that our identification strategy is based on variation across firms and can only spot differential changes in wages at the firm level. Nevertheless, when looking at the wage-age gradient for the economy as a whole, we find little evidence for relative wage adjustment (Figure A21 of the appendix), and if anything an increase in mature workers' wage, that could also be due to their changing composition due to the pension reform.

To directly assess this possibility, we exploited the fact that our reform provides variation in pension eligibility across age groups. The average rate of exit from employment by age among all workers in our sample in the years before (2009-2011) and after the reform (2012-2014) is shown in Figure A4 separately for men and women. While - due to the complex nature of pension eligibility - no single age is affected, one sees a clear increase in the age of exit from employment. In contrast to the large changes in employment, when we compare average FTE daily wages in the years before (2009-2011) and after the reform year (2012-2014), they barely changed for workers 50-59 (Figure 7). Within each period we see a rapid decline in wages as workers retire, most likely due to selection. The timing of this decline shifts with age, consistent with the increased retirement age. As a result, if at all wages tend to increase for workers in the range of 60 to 65 years range. However, given strong potential changes in the sample composition across ages as workers retire, we do not interpret this as causal.

6.2 Firm outcomes

A key advantage of our setting is that it allows us to study firms' economic responses to a rise in employment of older workers. Table 6 shows our findings in levels and Table 7 shows effects in per worker terms. We find that a rise in the share of older workers leads to an increase in value added and labor costs at constant average labor productivity or costs per worker.

To set the stage for this analysis, we first confirm that, based on the unbalanced panel including all INVIND firms, an increase in employment due to 55+ workers does not have any impact on the probability of firms' exit from and entry into the sample (Table A6 of the

[25] The Full Time Equivalent wage is obtained as the ratio between the sum of wage payments received in a given employment spell in a given year and the related days worked for full time workers; for part time workers the days worked are made equivalent to the full time ones by dividing by the full to part time hours. The denominator is thus based on contractual hours but the numerator also includes payments related to overtime hours (not separately identified in our data).

[26] Employment variations could entail a change in the observable characteristics in the three age brackets we are considering here, resulting in a change in average wage growth that is just due to a changing composition of the pool of workers. We thus run the same regression on a wage measure that is net of composition effects, equal to the constant plus the residuals of a wage regression on gender, citizenship and the individual's exact age measured in years (Table A5). Results are not affected by this adjustment for composition.

Appendix).[27]

Based on the balance sheet variables for our balanced sample (Table 6), we focus first on two measures of total labor costs. One is reconstructed from the individual workers' administrative records (INPS) and is equal to the total gross salary paid by the firm (total FTE days worked times Average FTE wage, Column 2); the other one is coming directly from the balance sheet data (Column 3). The two measures differ because labor costs from the balance sheet include expenses related to perks and benefits paid to workers and social security contributions paid by the firm, which are not included in the INPS data. Considering both measures, we find that an increase in the share of employment of older workers increased labor costs, an effect estimated to be statistically significantly different from zero in all of our specifications. The same is true for the effect of an increase in the share of older workers on total value added.

Our different OLS estimates are again very similar, while both the IV point coefficients and the standard errors increase. By design, IV estimates reduce the amount of variation used with respect to the corresponding OLS estimates, so an increase in the variance is to be expected. Given IV and OLS estimates are not statistically different from zero, we are careful in interpreting the differences in magnitudes. It is possible that the firms most affected by the increase in the mandatory retirement age were most constrained in terms of the labor supply of older workers, and hence experienced larger increase in value added and labor costs.

Finally, all specifications indicate that a rise in the employment of 55+ workers tends to raise capital investment. Only the panel data estimates are precisely estimated, while results obtained using the 2011-12 years only confirm this pattern but the estimates are not statistically significant from zero. It is likely that the unexpected shock taking place in 2012 and due to the unanticipated pension reform did not have a strong immediate impact on firms' investment plans.

Looking across the estimates, we find that - overall - the expansion in value added associated to an increase in 55+ workers is at least as large as the rise in the associated labor costs. Indeed unit labor costs[28] at the firm level remain unaffected.

Table 7 analyzes the response of balance sheet variables in per-worker terms. Overall, the effects of a rise in older workers' employment we find are substantially smaller and often not statistically different from zero.

The effects on labor costs per-worker are smaller compared to the ones on total labor costs for all specifications, though point estimates are generally positive. Small increases are plausible given that the share of workers with a relatively higher pay level increases. The coefficients on value added per worker tend not to be precisely estimated, and differ across specifications. There is no indication of a negative effect, and if at all the effect estimated for the reform years is positive. Across specifications and time intervals, we find a negative (albeit imprecisely estimated) effect on capital per-worker.

Taken together, these results show that an increased presence of older workers at the firm is associated with: *i)* an increase in employment in the other age classes, pointing to complementarity of workers between different age groups and to the fact that mature workers might be endowed with skills that are hard to replace; *ii)* a null or slight negative impact on wages of older workers themselves when employed in treated firms, *iii)* an increase in total labor costs that is in line with- if not smaller than - the one in value added; *iv)* no negative impact on average labor productivity, as measured by value added per worker.

In the remaining sections, we probe the sensitivity of these results and find them to be very robust.

[27] Additional analysis on firms' exit, for the *population* of Italian firms is reported in Table A8.

[28] Defined as the ratio between total labor costs and value added.

7 Robustness

7.1 Dynamic Results

In this section we estimate a set of 5 equations that are the dynamic versions of equation 3, estimated via both OLS and IV. The shock is the time–invarying–change in 55+ employment taking place in 2012 (the reform year) and the dependent variable is the cumulative change with respect to the year of the reform (2011). Since the reform was passed in December, we refer to the change with respect to 2012 as the immediate impact (the same discussed in Section 6). We refer to years 2013 and 2014 as the first and second year after the reform. The estimated coefficients on the change in the share of older workers in 2012 for these two years show the *c*umulative effects of the reform one or two years later. The coefficients on the models estimated for the two years before the reform (2010 and 2009) should not be statistically different from zero to confirm that, conditional on the controls, the increase in 55+ workers due to the reform should not be correlated with variations in the dependent variable that were already in place *before* the reform was introduced in 2012.

As before, we estimate the same set of regressions with OLS and IV specifications. Again, the point estimates of OLS and IV are generally qualitatively similar for different years. Not surprisingly the precision of the IV estimate declines for years other than the reform, and hence looking at both sets of estimates together provides a clearer picture of the dynamic effects. For all the main outcomes we report the corresponding graphs in Figures A5-A20 of the Appendix.

When we analyze employment outcomes across age classes, we find no different *pre trends* and precisely estimated increases in employment of younger and middle age workers that persist for up to two years after the year of the reform (Figures A5, A6 and A7 of the Appendix). The estimated effects are not statistically different in OLS and IV models. These estimates also confirm negligible effects on wages across age classes (Figures A8, A9 and A10).

As for firm outcomes, the pattern of the two measures of total labor costs found on impact is confirmed in the two years after the reform, while no differential *pre trends* are detected (Figures A11 and A12). The significant and persistent increase in total labor costs (similar in the two measures) is found to be somewhat smaller than the increase in total value added (Figure A13). We do not find a significant increase in total capital, and this is true also one or two years after the reform (Figure A14). Coherently, we find a slightly negative impact on capital per worker (Figure A15). Overall, these results confirm that the firm is able to increase production by taking advantage of the positive labor supply shock on 55+ workers without a rise in per worker labor costs or a decline worker productivity (Figures A16 to A20).

7.2 Heterogeneity

We consider several dimensions of heterogeneity across firms in order to shed light on the mechanisms driving the results found and to test their robustness.

In particular, we separate *young* from *old* firms, where firms are defined as *young* if their share of 55+ workers was below the median (10%) in 2011 and *old* otherwise. Similarly we define as *small* a firm whose size was below the median (170 employees) in 2011 and large otherwise.

Results of the IV estimates[29] – reported in Table 8 – show that the main patterns found on the whole sample are broadly confirmed in the subgroups. Even if the standard errors become large as the number of observations shrinks in the subgroups, some interesting patterns emerge: the positive effect on youth employment is larger in magnitude (but very imprecisely estimated) in relatively younger firms. Also, the positive effect on employment seems to be concentrated

[29]First stage statistics are reported in Table 1.

exclusively in relative larger firms, that are probably better able to adapt to an unexpected increase in the presence of 55+ workers by exploiting their internal labor market and expanding the scale of production.

7.3 An alternative shock measure

According to the results of this paper, an increase in older workers' presence in the firm can be absorbed fairly well by – relatively large – Italian firms. A positive shock on the labor supply of older workers determines – if anything – a reduction in their wages, and an increase in employment levels for workers of other ages. Higher employment levels are matched by an increase in value added. These results point to the presence of complementarity between workers of different age and to the existence of specific human capital generating replacement frictions such that reductions in the retirement flows affect firms' labor demand and outcomes. Indeed, we do not find any negative impact on value added per worker of an aging pool of employees.

The absence of negative employment effects on younger workers is in line with most of the literature looking at the possible crowding out effects generated by the labor supply shocks of specific segments of the population (female participation, migration).

Using similar data and exploiting the variation in older workers employment due to the 2012 reform, but focusing on smaller firms, two papers (Boeri et al. (2017) and Bovini and Paradisi (2019), later subsumed in Bianchi et al. (2020)) do find a trade off between older and younger workers in the short run. Both papers estimate the impact of the 2012 reform in a DD setting at the firm level. In Boeri et al. (2017) the main treatment is equal to the share of 55+ workers who had to postpone retirement over all 55+ employment; in Bianchi et al. (2020), it is equal to the average number of years of minimum retirement age delay for those individuals that, at the end of 2011, were at most 3 years far from being eligible to receive a public pension (defined as Close To Retirement, CTR); the treatment is divided by the number of individuals close to retirement. In both cases, the measure of the treatment is standardized by some measure of the number of individuals that were at risk of being treated. As such, the treatment only measures the intensity of the shock on a subgroup of workers employed at the firm, but not how relevant such shock is compared to the whole workforce employed at the firm.

As a further robustness check for our main results, we carry out a last set of estimates, that take into account also the number of years of unexpected pension delay and not only the share of workers affected. The IV estimates presented in Section 5.2 rely on the fact that, due to an unexpected reform taking place in 2012, a fraction of older workers had to postpone their retirement from that year to a later time. Nevertheless, the reform could have delayed the minimum retirement age by more than a year and also for individuals who were not expected to retire in 2012 but in the near future. We thus focus also on another measure of the shock implied by the reform, that is equal to the number of years of retirement delay for those individuals that were expected to retire in the near future, divided by the 2010 number of workers employed at the firm:[30]

$$T_j^{2012} = \frac{\sum_i YTR_{2012,i,j}|Law_{2012} - \sum_i YTR_{2012,i,j}|Law_{2011}}{EMPL_{2011,j}} \tag{6}$$

The variable YTR identifies Years To Retirement for workers i that, according to the law in place just before the 2012 reform were alternatively within one and five years from their MRA.

[30]This specification is close to the one adopted by Bovini and Paradisi (2019) later subsumed in Bianchi et al. (2020), with the exception that the shock is equal to the total number of years of pension eligibility delay among Close To Retirement (CTR) individuals divided by total employment rather than by the number of CTRs.

We thus estimate the following equation for year 2012-11:

$$\triangle y_{j,t} = \alpha + d_{st} + \beta * T_j^{2012} + \phi X_{j,2010} + \epsilon_{jt} \tag{7}$$

where T_j^{2012} is the treatment as defined in equation 6, $\triangle y_{j,t}$ is the year on year change in the dependent variable, d_s are sector fixed effects, and $X_{j,2010}$ are the usual controls (shares of 35-54 and 55+ workers in 2010).

First of all, we look at the impact of the treatment T_j^{2012} on employment variation of 55+ workers themselves, finding a positive coefficient irrespective of the number of YTR used to define the group of close to retirement individuals (Table 9). Positive effects of the treatment on employment are confirmed also for the other age classes (15-34 and 35-54). Results are confirmed as well when looking at Full Time Equivalent wages, and for all of the firm outcomes.

7.4 Additional evidence on the population of Italian firms

As a final robustness check we estimate equation 3 on an alternative dataset having partial info on the *population* of Italian firms (we are thus working with 1.5 million firms for the 2012-11 period). We do not use this dataset in the rest of the analysis because it does not include information on the years of social security contributions each worker has paid and – as such – it does not provide the information necessary to simulate the actual and expected MRA. For these reasons, the additional estimates cannot rely on an IV strategy. We estimate the first differences OLS specification of equation 3 in the reform years (2011-2012).

Results reported in Table A8 are again in line with those obtained with our sample of relatively large firms and show a positive correlation between 55+ employment variation and employment variation in other age classes, a negligible impact on wages and positive effects on capital and value added.

8 Conclusions

In response to population aging, in the last decades many governments provided incentives to postpone retirement through increases in the statutory retirement age or through tax breaks. However, the increased participation of older workers has raised two main concerns. There are fears that older workers may crowd out younger cohorts in the labor market, by reducing their work opportunities. A larger presence of older workers may hamper firms' productivity and future growth since older workers, even if more experienced, may be less innovative and less willing to take risks than younger cohorts.

This paper analyzes the causal effects of a short-run increase in employment of older workers on firms' input mix, wages, labor costs, total capital, value added, and average labor productivity. After showing that in the Italian institutional setting older workers mostly retire after reaching pension age, we exploit a recent reform of pension eligibility as an exogenous increase in the presence of older workers at the firm level. Effects are estimated based on a unique matched employer, employee, balance sheet data set for the period 2010-2014.

We find that an unexpected increase in the share of older workers leads to a positive impact on young and middle-age employment. An exogenous 10% increase in the number of old workers implies a 1.8% increase in the number of young and 1.3% of middle-aged workers. Total labor costs increase in line with employment, and remain broadly constant in per-worker terms. Total value added increases and per worker labor productivity is constant. These adjustments occur with little changes in daily wages. Despite substantial aggregate employment responses, we also find no evidence of aggregate wages for older workers.

These results are consistent with a model in which firm-specific human capital or market frictions make it costly to replace older, higher-tenured workers in the market. Younger and middle-aged workers appear to be imperfect substitutes, and in our setting are likely complements to older workers. The fact that labor costs increase in line with employment and tend to respond less than value added signals that firms were able to adjust smoothly, and may have benefited, from the shock implied by the pension reform. There is no evidence that older workers may have been overpaid relative to their productivity, or that their increase implied a burden to the firm. Overall, the absence of any negative impact on value added per worker seems to point out that concerns on the impact of an aging workforce on productivity might be overstated, in line with the findings of Acemoglu and Restrepo (2018).

Generalizing our results requires some caution. First, for data reasons, in our main results we focus only on large firms, which are less likely to be credit constrained and perhaps more able to expand employment. While we show our findings are robust for a broader sample that includes smaller firms, a separate analysis with high-quality economic data for smaller firms may be fruitful for future work. Second, since the effective retirement age in Italy is not very high (62 years old for men and 61 for women; corresponding figures at OECD level are 65 and 63.6, respectively), the non-negative effects on firms' outcomes we found might be driven by the fact that incumbent older workers are not too old and thus still productive. Finally, by design, our analysis is neither equipped to capture market-level responses or to isolate longer-term relationships between population aging and economic outcomes.

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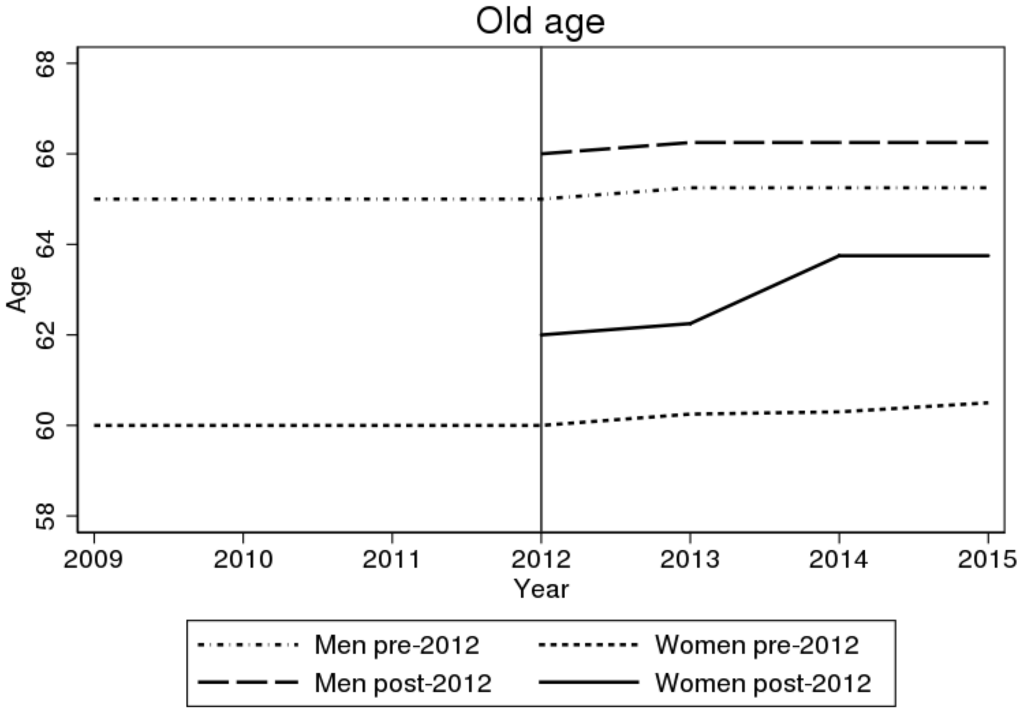
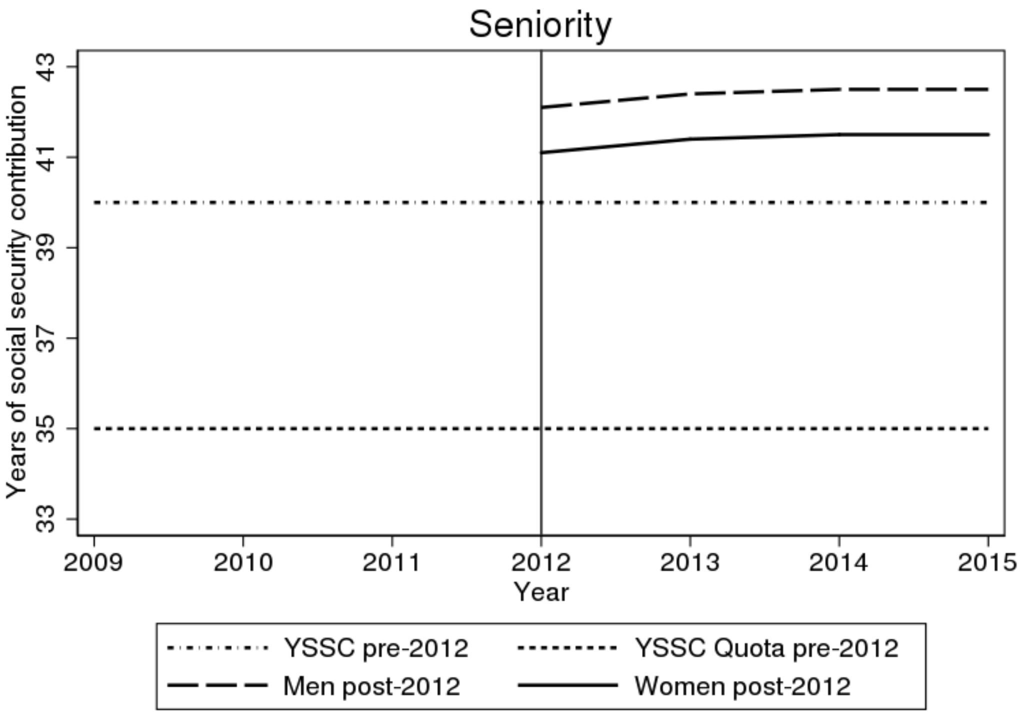
Figures and Tables

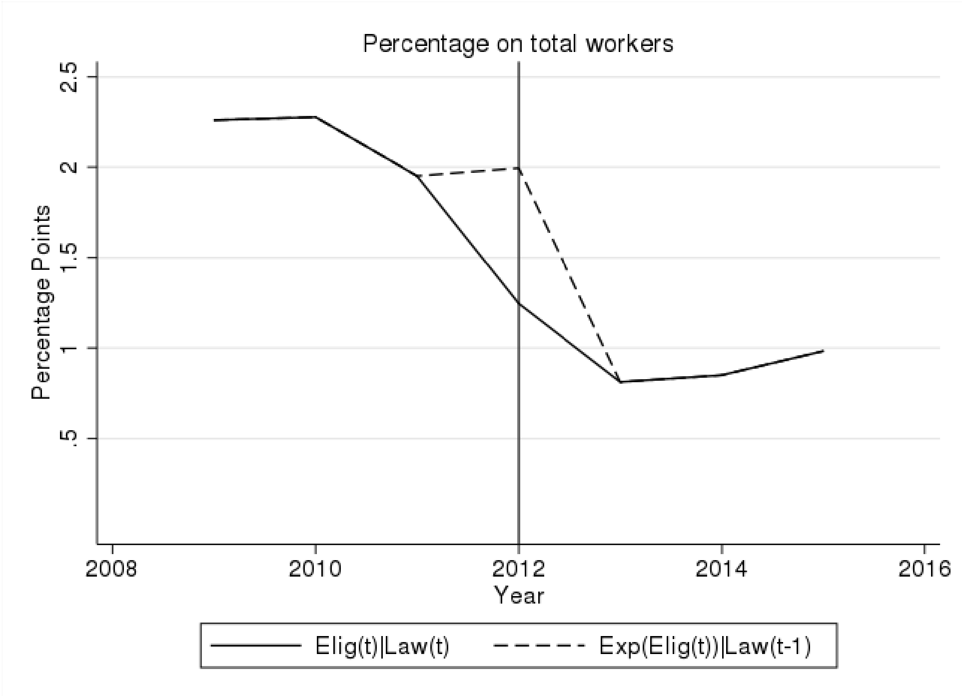
Figure 1: **Public pension eligibility rules, by type**



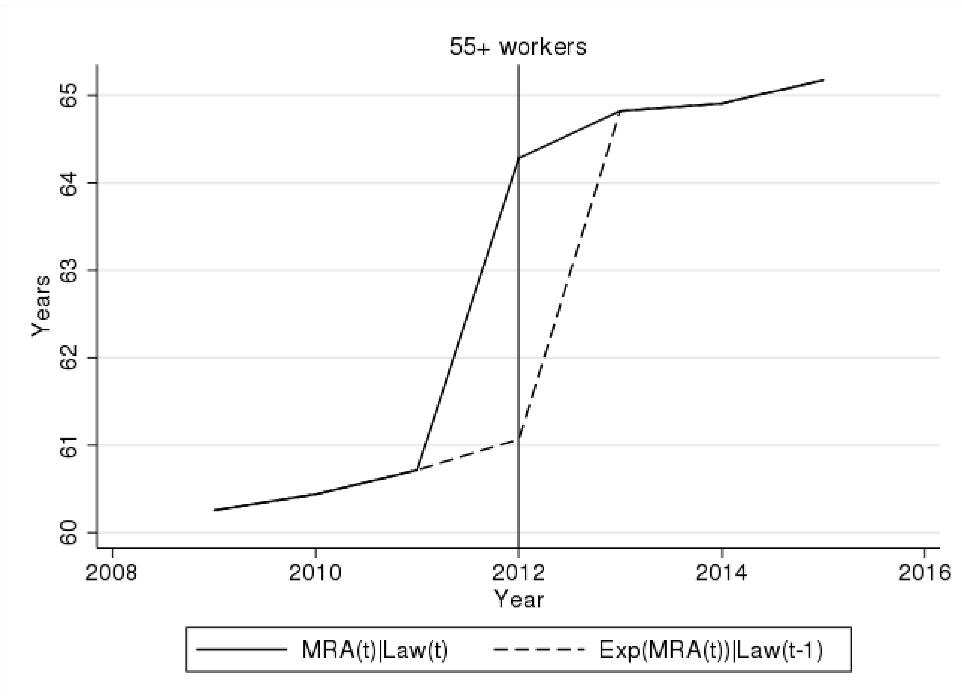


Notes: YSSC stands for Years of Social Security Contributions. Under the seniority scheme, before the 2011 reform the eligibility rules were the same for men and women. One option referred only to the number of accrued YSSC (*YSSC pre-2012*); the second one referred to a combination of requirements on the number of YSSC and age (*YSSC Quota pre-2012*). After the reform, the second option - the Quota - was abolished. The seniority pension scheme requires a given number of accrued YSSC which differs across genders.

Figure 2: **Exptected and actual public pension eligibility and MRA**

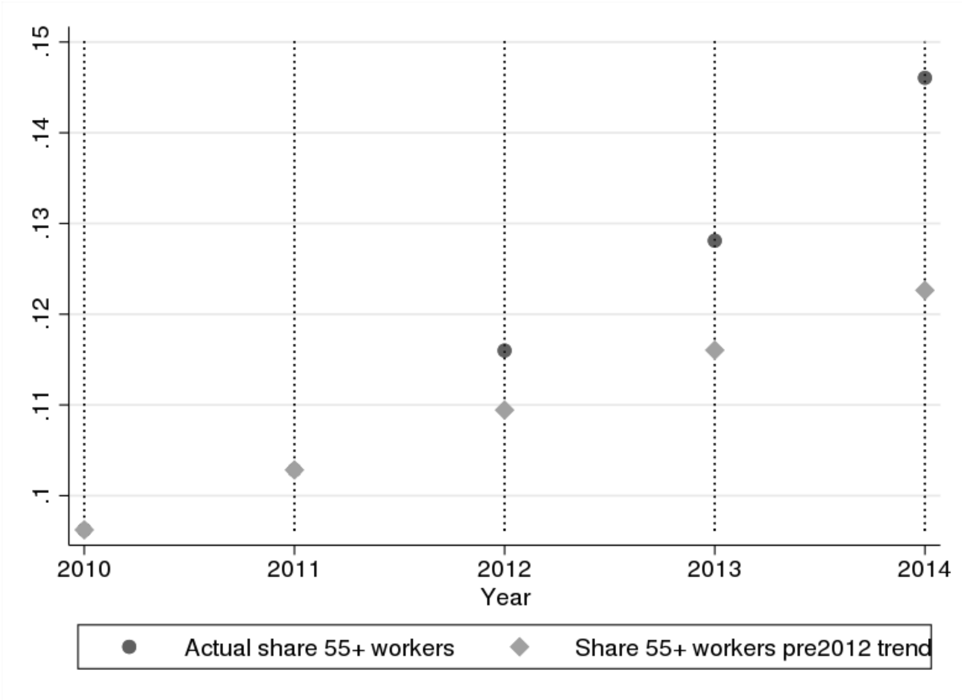


Notes: Our calculations based on INPS-INVIND data. Solid line: share of workers who are eligible for a public pension in year t according to the law in place in year t, $ELIG_{i,t}|Law_t$. Dotted line: expected share of workers who are eligible for a public pension in year t according to the law in place in year $t-1$, $ELIG_{i,t}|Law_{t-1}$. The solid vertical line identifies the first year in which the pension reform we analyze was implemented.



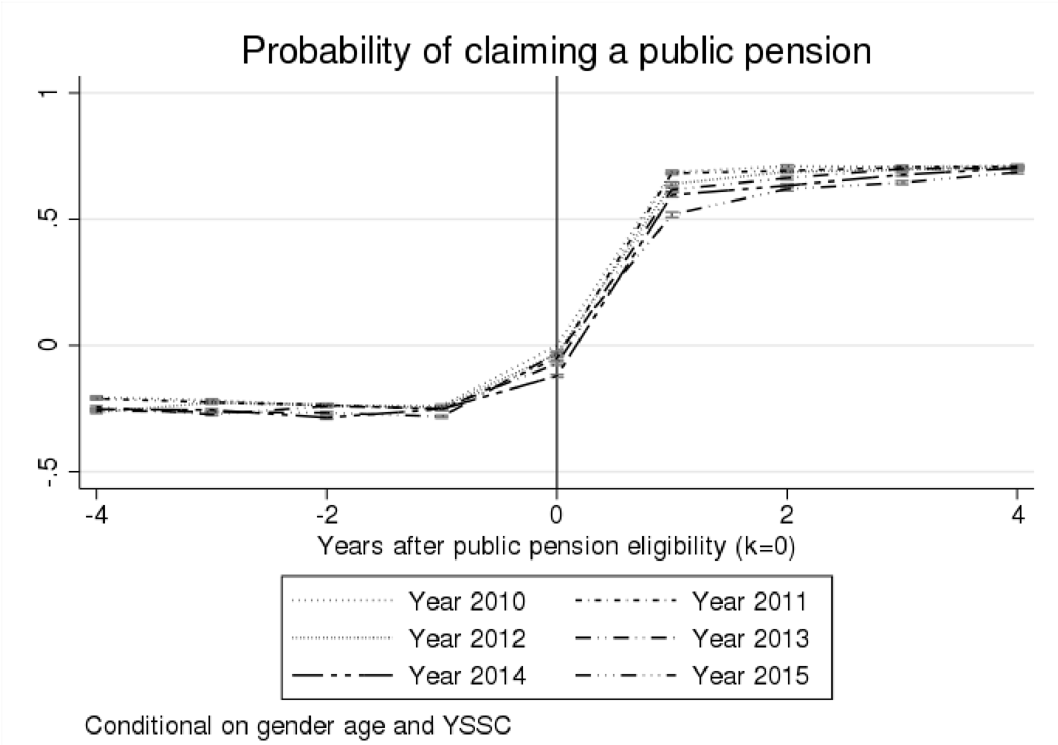
Notes: Our calculations based on INPS-INVIND data. Solid line: Average Minimum Retirement Age in year t according to the law in place in year t, $MRA_{i,t}|Law_t$. Dotted line: expected share of workers who are eligible for a public pension in year t according to the law in place in year $t-1$, $MRA_{i,t}|Law_{t-1}$. The solid vertical line marks the first year in which the pension reform we analyze was implemented.

Figure 3: **The evolution of the share of 55+ workers (actual and pre-2012 trend)**

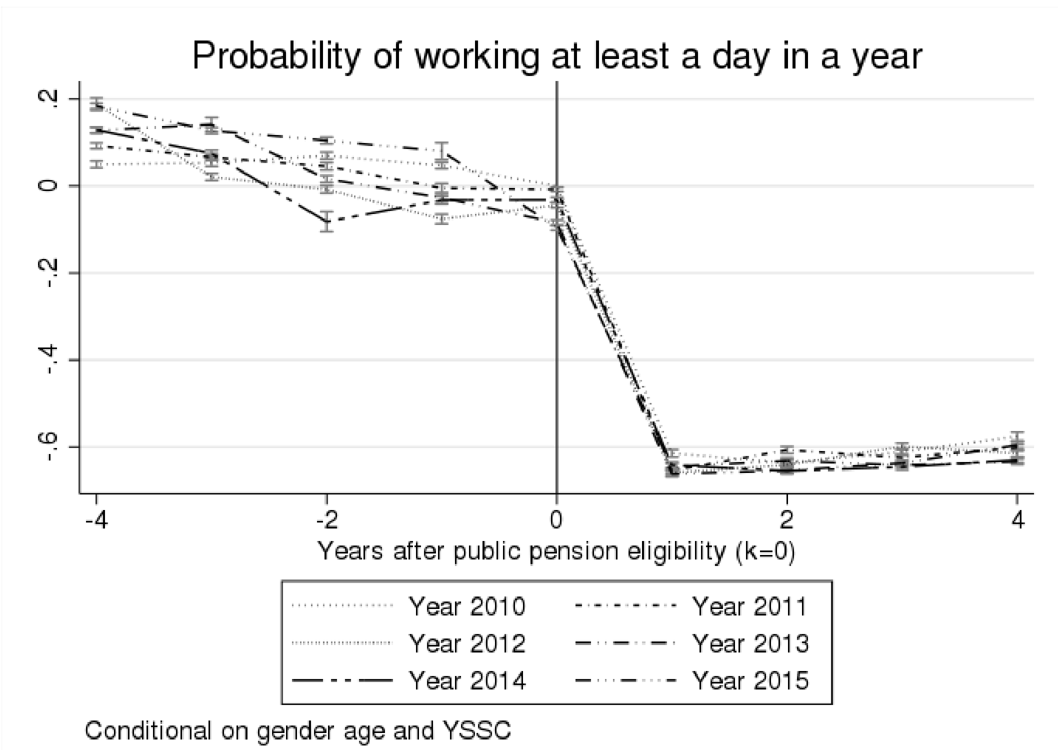


Notes: Our calculations on INVIND sample used in the analysis, see Table **??** for descriptive statistics. In dark grey: the actual share of 55+ workers; in light grey: the predicted line over the pre-2012 trend.

Figure 4: **Claiming and retirement around pension eligibility**

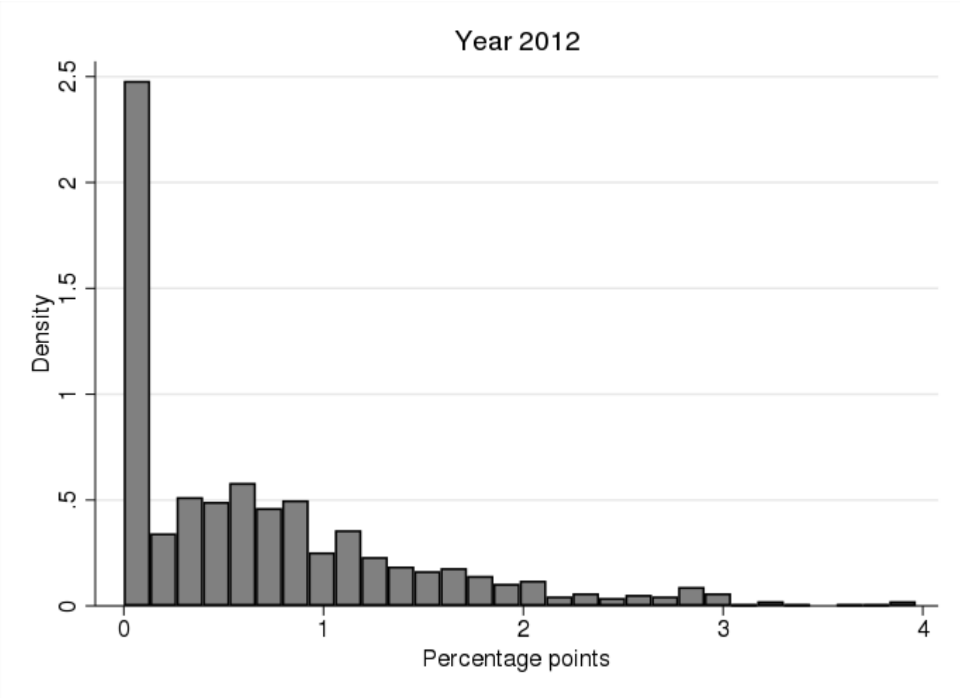


Notes: Our calculations on INPS data. Results of an auxiliary regression estimating the probability to claim pension benefits as a function of the time distance (measured in years) to retirement eligibility. Point estimates and 95% confidence intervals. *Information on actual benefit claim is available only for a subsample of workers.*



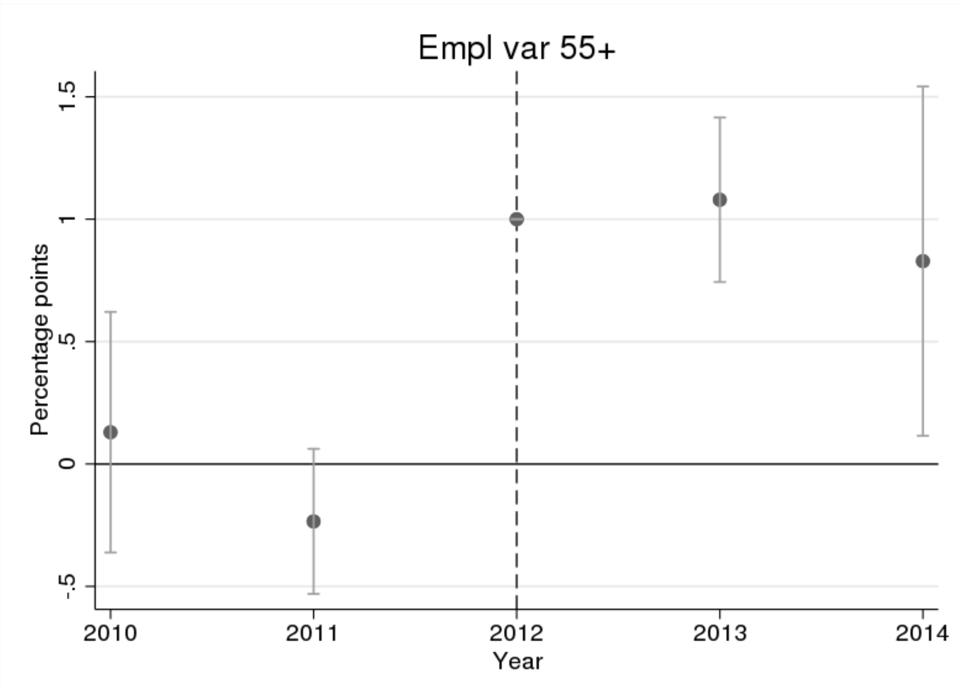
Notes: Our calculations on INPS data. Results of an auxiliary regression estimating the probability of being employed as function of the time distance (measured in years) to retirement eligibility. Point estimates and 95% confidence intervals. *Information on actual benefit claim is available only for a subsample of workers.*

Figure 5: **55+ workers unexpectedly losing eligibility in 2012: firm level share on total workforce**



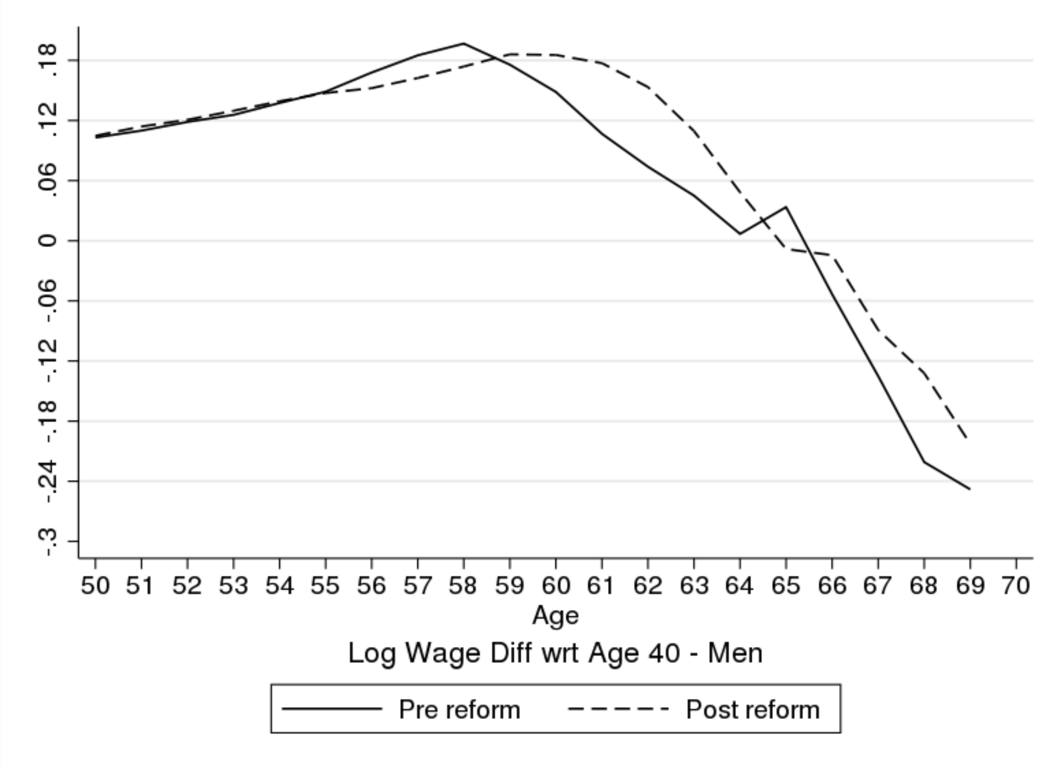
Notes: Our calculations on INPS data.

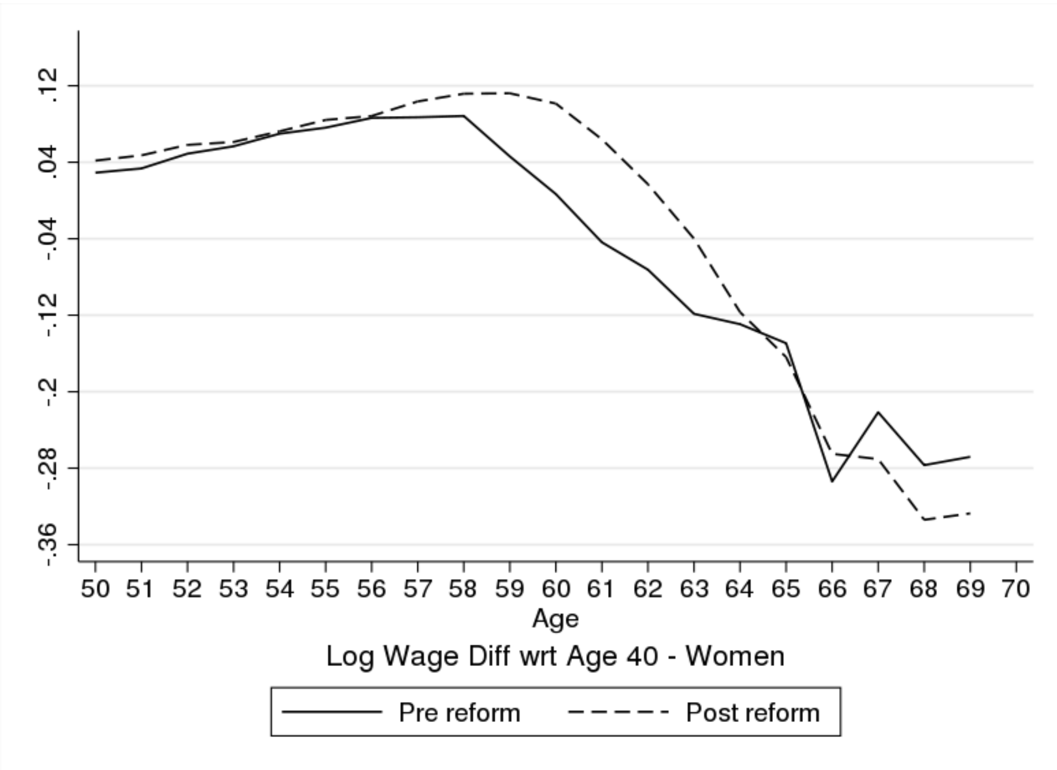
Figure 6: **The 2012 shock on 55+ employment: pre-trends and dynamic effects**



Notes: The graph reports estimates of a regression of the instrumented 55+ employment change in 2012 as in equation 5 of Subsection 5.2.1 on up to two leads and two lags of cumulative 55+ employment change.

Figure 7: **The wage-age gradient for mature workers in the overall economy**





Notes: Our calculations on INPS data. Data cover the whole private non agricultural sector; only employees working at least 150 days in a given year are included. Each wage level is normalized to the average for 40-44 years old in each year.

Table 1: **First stage regression. Years 2011-2012**

	All firms		Young		Old		Small		Big	
	Coef.	S.e.	Coef.	S.e.	Coef.	S.e.	Coef.	S.e.	Coef.	S.e.
$\frac{ELIG_{j,2012}\vert Law_{2011}}{EMPL_{j,2011}}$	-0.39***	(0.10)	-0.38***	(0.08)	-0.40***	(0.12)	-0.35***	(0.11)	-0.53***	(0.22)
$\frac{ELIG_{j,2012}\vert Law_{2011} - ELIG_{j,2012}\vert Law_{2012}}{EMPL_{j,2011}}$	0.56***	(0.18)	0.32***	(0.12)	0.61***	(0.22)	0.56***	(0.22)	0.69***	(0.38)
Obs	1025		437		588		507		518	
F-test	31.99		9.72		19.24		16.7		21.43	

Notes: First stage regression (equation 5). Dependent variable:

$$\frac{OLD_{j,2012} - OLD_{j,2011}}{EMPL_{j,2011}}$$

The average predicted change in employment due to the increase 55+ workers caused by the reform is equal to 0.4 percentage points.
* significant at 10%; ** significant at 5%; *** significant at 1%.

Table 2: **Effects on employment, by age class. Years: 2010-2014 or 2012-11**

	15-34	35-54	15-34	35-54
	Balanced panel		Unbalanced panel	
FD OLS				
Net empl var 55+	0.391***	1.466***	0.463***	1.694***
	(0.0419)	(0.140)	(0.0493)	(0.149)
Obs	5125	5125	7101	7101
FD OLS with FE				
Net empl var 55+	0.364***	1.467***	0.411***	1.610***
	(0.0436)	(0.160)	(0.0451)	(0.154)
Obs	5125	5125	7101	7101
FD OLS (Years 2011-12)				
	0.407***	1.629***	0.557***	1.700***
	(0.0547)	(0.268)	(0.0735)	(0.184)
Obs	1025	1025	1960	1960
FD IV (Years 2011-12)				
Net empl var 55+	0.522**	0.786*	0.557	0.848**
	(0.262)	(0.405)	(0.344)	(0.401)
Obs	1025	1025	1960	1960

Notes: Estimates of equation 3 on the balanced panel. Regressions include as additional controls: the share of 35-54 and 55+ workers in 2010, sector fixed effects and year fixed effects (not included in the one year regressions 2011-12). First stage statistics for the IV estimates are reported in Table 1. Standard errors in brackets clustered at the firm level.
* significant at 10%; ** significant at 5%; *** significant at 1%.

Table 3: **Effects hirings and separations, by age. Years: 2010-2014.**

	Hiring rate			Separation rate		
	15-34	35-54	55+	15-34	35-54	55+
FD OLS						
Net empl var 55+	0.441***	1.197***	0.352***	0.0501	-0.269***	-0.648***
	(0.0553)	(0.131)	(0.0439)	(0.0443)	(0.0978)	(0.0439)
Obs	5125	5125	5125	5125	5125	5125
FD OLS with FE						
Net empl var 55+	0.280***	0.895***	0.281***	-0.0847***	-0.572***	-0.719***
	(0.0414)	(0.133)	(0.0469)	(0.0287)	(0.0808)	(0.0469)
Obs	5125	5125	5125	5125	5125	5125
FD OLS (Years 2011-12)						
	0.409***	1.541***	0.536***	0.00152	-0.0883	-0.464***
	(0.0802)	(0.295)	(0.136)	(0.0707)	(0.124)	(0.136)
Obs	1025	1025	1025	1025	1025	1025
FD IV (Years 2011-12)						
Net empl var 55+	0.480	0.484	0.102	-0.0422	-0.302	-0.898***
	(0.498)	(0.649)	(0.256)	(0.437)	(0.565)	(0.256)
Obs	1025	1025	1025	1025	1025	1025

Notes: Estimates of equation 3. Regressions include as additional controls: the share of 35-54 and 55+ workers in 2010, sector fixed effects and year fixed effects (not included in the one year regressions 2011-12). First stage statistics for the IV estimates are reported in Table 1. Standard errors in brackets clustered at the firm level.
* significant at 10%; ** significant at 5%; *** significant at 1%.

Table 4: **Net employment variation by contract type. Years: 2010-2014.**

	Fixed term contract			Permanent contract		
	15-34	35-54	55+	15-34	35-54	55+
FD OLS	0.125***	0.167***	0.0866***	0.266***	1.300***	0.913***
Net empl var 55+	(0.0218)	(0.0300)	(0.0173)	(0.0352)	(0.138)	(0.0173)
Obs	5125	5125	5125	5125	5125	5125
FD OLS with FE						
Net empl var 55+	0.107***	0.154***	0.0950***	0.257***	1.313***	0.905***
	(0.0200)	(0.0331)	(0.0200)	(0.0402)	(0.158)	(0.0200)
Obs.	5125	5125	5125	5125	5125	5125
FD OLS (Years 2011-12)						
	0.112***	0.187***	0.0552***	0.295***	1.442***	0.945***
	(0.0352)	(0.0395)	(0.0145)	(0.0561)	(0.260)	(0.0145)
Obs	1025	1025	1025	1025	1025	1025
FD IV (Years 2011-12)						
Net empl var 55+	0.332*	-0.120	0.0483	0.190	0.906**	0.952***
	(0.188)	(0.181)	(0.0545)	(0.167)	(0.359)	(0.0545)
	1025	1025	1025	1025	1025	1025

Notes: Estimates of equation 3. Regressions include as additional controls: the share of 35-54 and 55+ workers in 2010, sector fixed effects and year fixed effects (not included in the one year regressions 2011-12). First stage statistics for the IV estimates are reported in Table 1. Standard errors in brackets clustered at the firm level.
* significant at 10%; ** significant at 5%; *** significant at 1%.

Table 5: **Effects on FTE wages, by age class. Years: 2010-2014.**

VARIABLES	15-34	35-54	55+
FD OLS	-0.057	-0.036	-0.507***
Net empl var 55+	(0.0567)	(0.045)	(0.105)
	5113	5125	5088
Obs.			
FD OLS with firm FE			
Net empl var 55+	-0.044	-0.030	-0.506***
	(0.065)	(0.046)	(0.111)
Obs.	5113	5125	5088
FD (Years 2011-12)			
	-0.100	-0.008	-0.363
	(0.168)	(0.104)	(0.243)
	1022	1025	1020
FD IV (Years 2011-12)			
Net empl var 55+	-0.132	0.0926	-0.456
	(0.596)	(0.433)	(1.005)
Obs.	1022	1025	1020

Notes: Estimates of equation 3. Regressions include as additional controls: the share of 35-54 and 55+ workers in 2010, sector fixed effects and year fixed effects (not included in the one year regressions 2011-12). First stage statistics for the IV estimates are reported in Table 1. Standard errors in brackets clustered at the firm level.
* significant at 10%; ** significant at 5%; *** significant at 1%.

Table 6: **Firm outcomes. Years: 2010-2014.**

	Labor cost		Value	Unit Labor costs		
VARIABLES	**INPS**	**Balance sheet**	**Added**	**INPS**	**Balance sheet**	**Capital**
FD OLS	0.773***	0.682***	0.729***	0.0255	-0.0448	0.434***
Net empl var 55+	(0.0594)	(0.0762)	(0.115)	(0.0968)	(0.0824)	(0.104)
	5116	5116	5116	5116	5116	5116
Obs						
FD OLS with FE						
Net empl var 55+	0.499***	0.403***	0.415***	0.0841	-0.00623	0.283***
	(0.0600)	(0.0757)	(0.136)	(0.116)	(0.102)	(0.0999)
Obs	5116	5116	5116	5116	5116	5116
FD OLS (Years 2011-12)						
	0.645***	0.595***	0.929***	-0.148	-0.258*	0.197
	(0.0857)	(0.104)	(0.190)	(0.169)	(0.156)	(0.195)
Obs	1025	1025	1025	1025	1025	1025
FD IV (Years 2011-12)	1.678***	1.585**	3.767**	-0.217	-0.481	0.706
Net empl var 55+	(0.609)	(0.640)	(1.759)	(1.139)	(1.035)	(0.982)
Obs	1025	1025	1025	1025	1025	1025

Notes: Estimates of equation 3. Labor cost-INPS is the total labor cost obtained by multiplying the average wage by the number of FTE working days in INPS data. Labor cost-Balance sheet is the total labor cost according to the firm balance sheet. Regressions include as additional controls: the share of 35-54 and 55+ workers in 2010, sector fixed effects and year fixed effects (not included in the one year regressions 2011-12). First stage statistics for the IV estimates are reported in Table 1. Standard errors in brackets clustered at the firm level.
* significant at 10%; ** significant at 5%; *** significant at 1%.

Table 7: **Firm outcomes - per worker levels. Years 2010-14**

		Labor cost		Value
VARIABLES	**Capital**	**INPS**	**Balance sheet**	**Added**
FD OLS	-0.291**	0.109***	0.0720	0.0572
Net empl var 55+	(0.127)	(0.0368)	(0.0533)	(0.106)
Obs	5116	5116	5116	5116
FD OLS with FE	-0.159	0.0938**	0.0474	-0.0389
Net empl var 55+	(0.137)	(0.0443)	(0.0629)	(0.129)
Obs	5116	5116	5116	5116
FD OLS (Years 2011-12)	-0.143	0.228***	0.225**	0.461**
	(0.219)	(0.0637)	(0.0901)	(0.190)
Obs	1025	1025	1025	1025
FD IV (Years 2011-12)	-0.473	0.327	0.213	1.610
Net empl var 55+	(1.305)	(0.379)	(0.507)	(1.396)
Obs	1025	1025	1025	1025

Notes: Estimates of equation 3. Labor cost-INPS is the total labor cost obtained by multiplying the average wage by the number of FTE working days in INPS data. Labor cost-Balance sheet is the total labor cost according to the firm balance sheet. Regressions include as additional controls: the share of 35-54 and 55+ workers in 2010, sector fixed effects and year fixed effects (not included in the one year regressions 2011-12). Standard errors in brackets clustered at the firm level. First stage statistics for the IV estimates are reported in Table 1.
* significant at 10%; ** significant at 5%; *** significant at 1%.

Table 8: **Heterogeneity**

	Net empl var		Wage var			Labor cost		Value added	
VARIABLES	**15-34**	**35-54**	**15-34**	**35-54**	**55+**	**Tot**	**p.w.**	**Tot**	**p.w.**
YOUNG									
Net empl var 55+	1.367	0.350	-2.157	1.748	-1.037	5.382*	3.940*	8.852*	6.420
	(1.247)	(1.306)	(2.235)	(1.929)	(5.896)	(3.120)	(2.336)	(5.371)	(5.002)
Observations	437	437	437	437	432	437	437	437	437
OLD									
Net empl var 55+	0.441*	0.840*	0.136	-0.213	-0.535	1.126**	-0.181	3.025*	0.944
	(0.237)	(0.431)	(0.610)	(0.454)	(0.877)	(0.570)	(0.516)	(1.721)	(1.355)
Observations	588	588	585	588	588	588	588	588	588
SMALL									
Net empl var 55+	0.299	0.438	-0.297	0.204	-0.234	1.574**	0.201	2.743	0.647
	(0.285)	(0.555)	(0.735)	(0.517)	(1.209)	(0.729)	(0.599)	(1.774)	(1.496)
Observations	507	507	504	507	503	507	507	507	507
LARGE									
Net empl var 55+	1.090*	1.828**	0.260	-0.0507	-2.154	1.062	-0.129	6.141	4.121
	(0.627)	(0.931)	(0.815)	(0.654)	(1.512)	(0.945)	(0.770)	(3.909)	(2.978)
Observations	518	518	518	518	517	518	518	518	518

Notes: Estimates of equation 3. Regressions include as additional controls: the share of 35-54 and 55+ workers in 2010, sector fixed effects. All dependent variables come from balance sheet data (CEBI or INVIND). All regressions include sector and year fixed effects, the share of 35-54 and 55+ in 2010. Standard errors in brackets clustered at the firm level.

* significant at 10%; ** significant at 5%; *** significant at 1%.

Table 9: **An alternative shock measure**

		$0 <= YTR <= 1$		$0 <= YTR <= 2$		$0 <= YTR <= 3$		$0 <= YTR <= 4$		$0 <= YTR <= 5$	
Net empl var	15-34	0.058	(0.047)	0.0423	(0.028)	0.036*	(0.020)	0.029*	(0.015)	0.038***	(0.011)
	35-54	0.327**	(0.127)	0.172*	(0.093)	0.086**	(0.037)	0.078**	(0.033)	0.079***	(0.026)
	55+	0.164***	(0.058)	0.100**	(0.043)	0.069***	(0.018)	0.059***	(0.015)	0.044***	(0.011)
Delta wage	15-34	0.054	(0.086)	0.041	(0.051)	-0.013	(0.031)	0.011	(0.026)	0.010	(0.019)
	35-54	0.005	(0.063)	0.046	(0.034)	0.015	(0.022)	0.024	(0.018)	0.018	(0.015)
	55+	0.162	(0.163)	-0.027	(0.078)	-0.017	(0.057)	0.004	(0.046)	-0.022	(0.039)
Firm outcomes	Total										
Capital		0.392**	(0.167)	0.123	(0.079)	0.117**	(0.056)	0.071	(0.048)	0.070*	(0.039)
Labor cost	INPS	0.287**	(0.115)	0.269***	(0.059)	0.168***	(0.035)	0.155***	(0.031)	0.154***	(0.029)
Labor cost	Balance sheet	0.257**	(0.125)	0.252***	(0.057)	0.177***	(0.036)	0.149***	(0.0312)	0.148***	(0.0268)
Value added		0.301	(0.245)	0.320***	(0.121)	0.254***	(0.084)	0.246***	(0.068)	0.244***	(0.055)
Firm outcomes	Per worker										
Capital		0.367	(0.232)	-0.080	(0.112)	-0.031	(0.081)	-0.069	(0.069)	-0.051	(0.058)
Labor cost	INPS	0.137**	(0.0665)	0.0875**	(0.0346)	0.0267	(0.0225)	0.0218	(0.0189)	0.023	(0.016)
Labor cost	Balance sheet	0.120	(0.088)	0.061	(0.043)	0.013	(0.031)	0.0022	(0.026)	0.009	(0.020)
Value added		0.158	(0.193)	0.086	(0.110)	0.051	(0.078)	0.0682	(0.063)	0.088*	(0.049)

Notes: Estimates of equation 7. Regressions include as additional controls: the share of 35-54 and 55+ workers in 2010, sector fixed effects. All regressions include sector and year fixed effects, the share of 35-54 and 55+ in 2010. Standard errors in brackets clustered at the firm level.
* significant at 10%; ** significant at 5%; *** significant at 1%.

A Appendix

A.1 Details on the institutional setting

The Italian welfare system features two main public pension schemes: *old age* and *seniority*.

As for the *old age* pension scheme, before the reform the retirement age was 60 for women and 65 for men, requiring also a minimum number of accrued years of contribution.[31] The Fornero pension reform swiftly increased the retirement age for all workers up to 67 by 2020, both for men and for women, with at least 20 years of paid social security contributions; moreover, the reform allowed all individuals to retire at 70, as long as they accrued at least 5 years of contribution.

As for the *seniority* pension scheme, before the reform, eligibility required either 40 years of paid contributions (irrespective of age) or a mix of age and years of social security contributions, the so called "quota system" (for instance, the sum of age and years of social security contribution should have been 96 in 2011, with at least 60 years of age and 35 years of social security contribution). The Fornero reform abolished the "quota system" and raised the minimum years of paid contribution in 2012 from 40 to 42 for men, to 41 for women.[32] Finally, the new rules in place since 2012 allowed workers who were already eligible for a public pension when the bill passed to retire under the pre-reform rules, without losing their eligibility. This option was not available before the reform, since workers could retire in a given year only if eligible under the rules in place that given year.

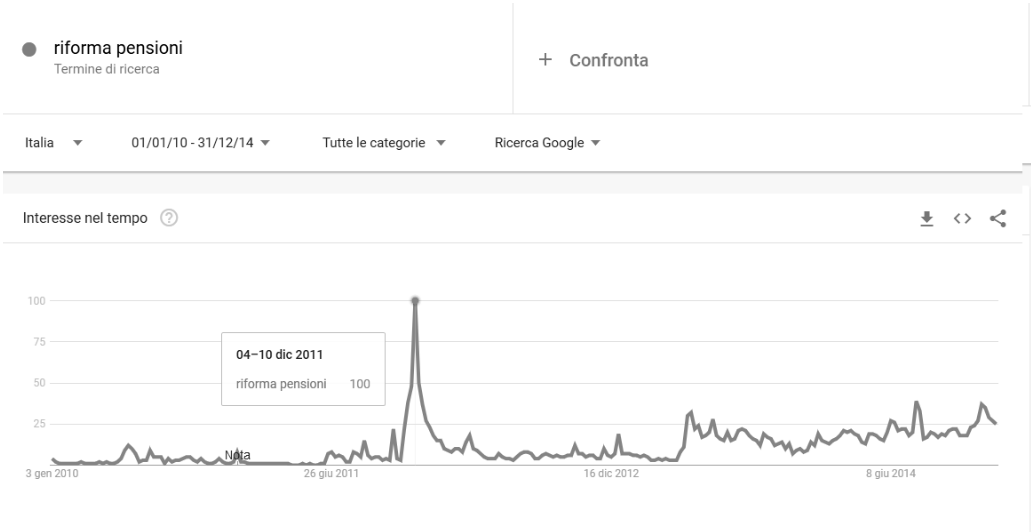
Finally, early retirement is available only for women and has not been affected by the reform. Such an option, despite the increase in the take-up after the reform, is rarely used, given that it implies, on average, a 35% cut in the monthly transfer (Italian Institute of Social Security, 2016). The maximum value of the take-up rate was not more than 20% in 2015 (around 11% before the reform). There is no mandatory retirement and working after retirement is not prohibited.

[31] Eligibility for old age scheme also required 20 accrued years of contribution. Before the Fornero reform, the requirement was of 5 years for workers who had started to work since January 1996 (under the defined contribution scheme), while it was already 20 for those who had started to work before January 1996 (under the defined benefit scheme).

[32] In 2013, the minimum number of required years of contributions rose to 43 for men and 42 for women; from 2014 onward to 44 for men and 43 for women, respectively.

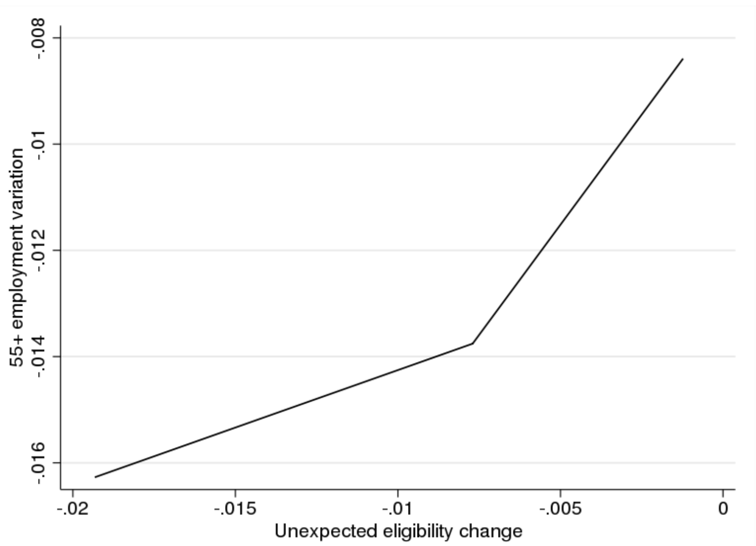
A.2 Additional figures and tables

Figure A1: **Google searches for "Riforma pensioni"**



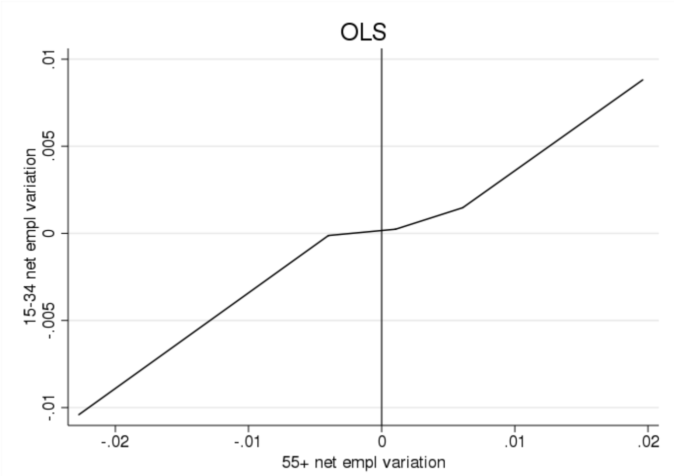
Notes: Downloaded from https://trends.google.it/trends/ on February, 19, 2020.

Figure A2: **First stage**

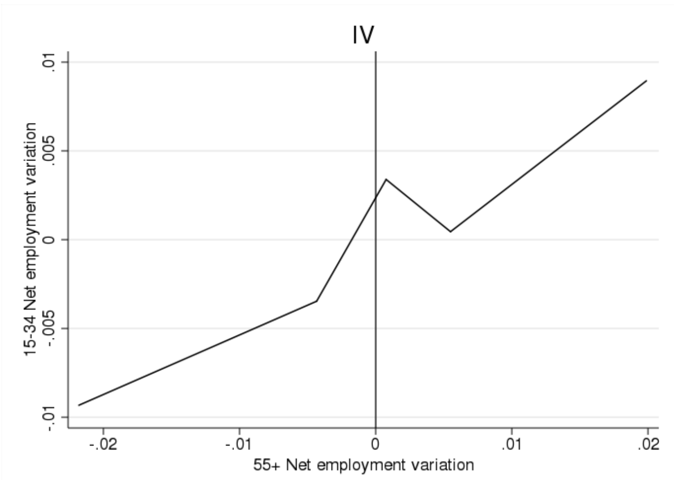


Notes: For each quintile of the distribution of eligibility change for 55+ workers expressed as a share of total employment, the X axis reports the average eligibility change for 55+ workers expressed as a share of total employment and the Y axis reports the average change in 55+ employment as a share of total employment.

Figure A3: **A closer look at the residuals**

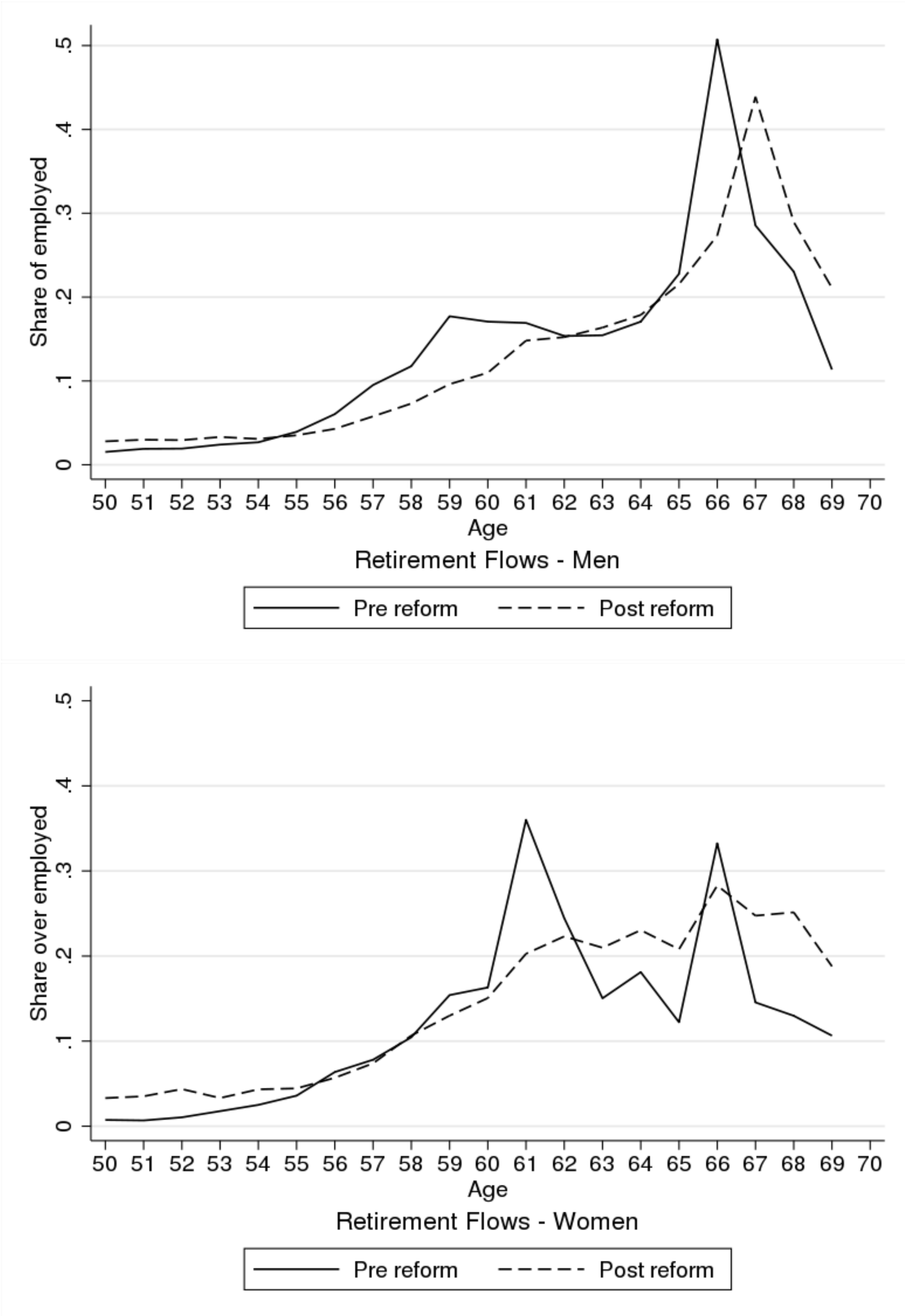


Notes: The figure is based on equation 3. X axis reports - for each quintile - the average of the residuals of a regression of the net employment variation of 55+workers on controls. Y axis reports the corresponding averages for 15-34 residuals.



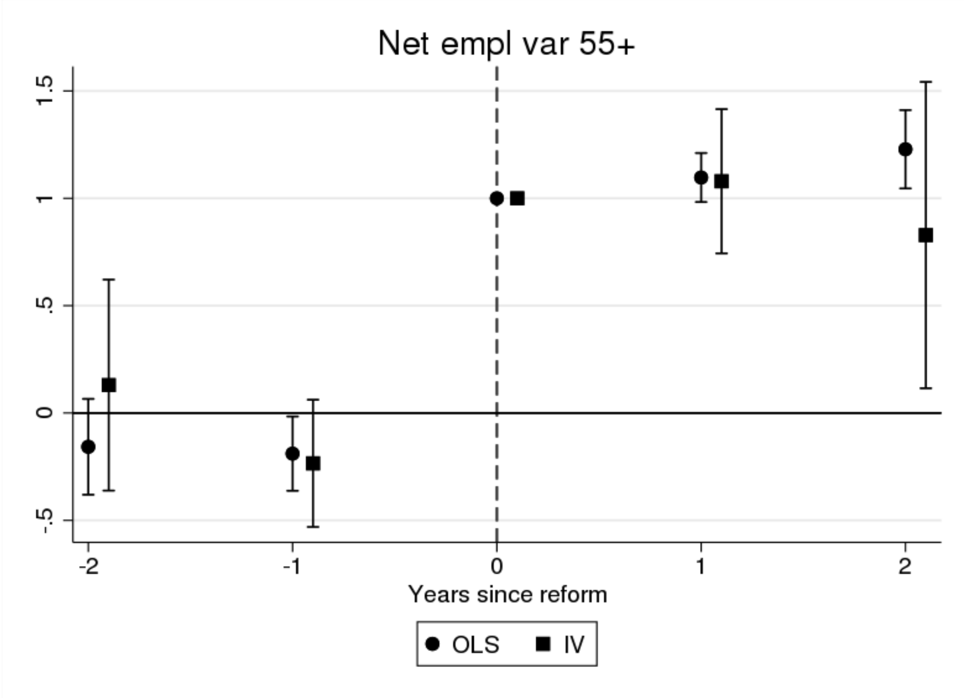
Notes: The figure is based on the IV estimates for equation 3. X axis reports - for each quintile - the average of the residuals of a regression of the *instrumented* net employment variation of 55+ workers on controls. Y axis reports the corresponding averages for 15-34 residuals.

Figure A4: **Retirement flows by exact age, 55+ workers**



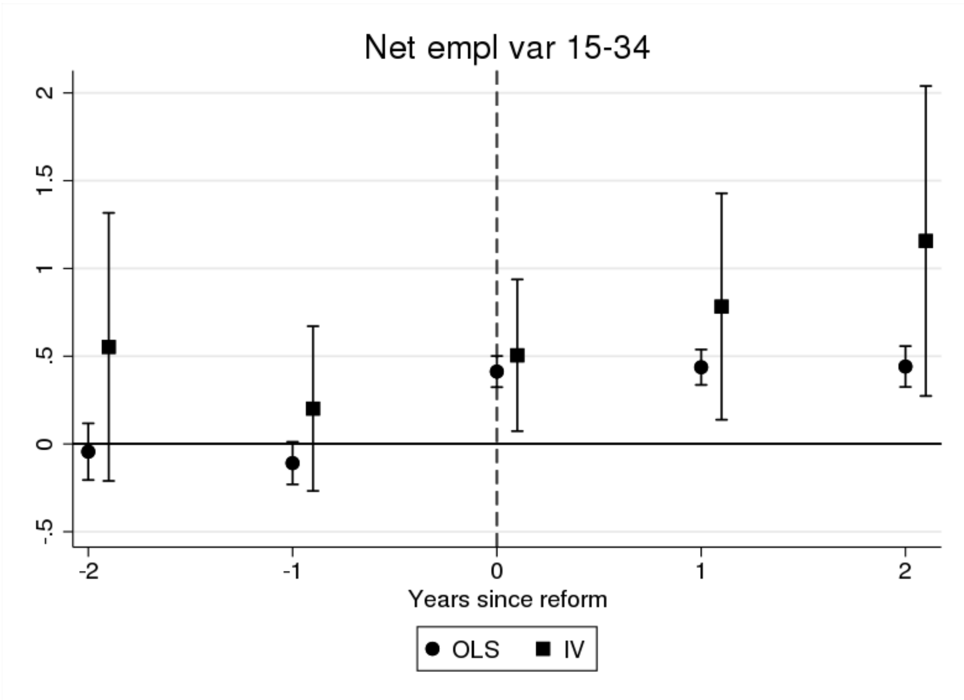
Notes: Our calculations on INPS data

Figure A5: **Estimated cumulative effects**



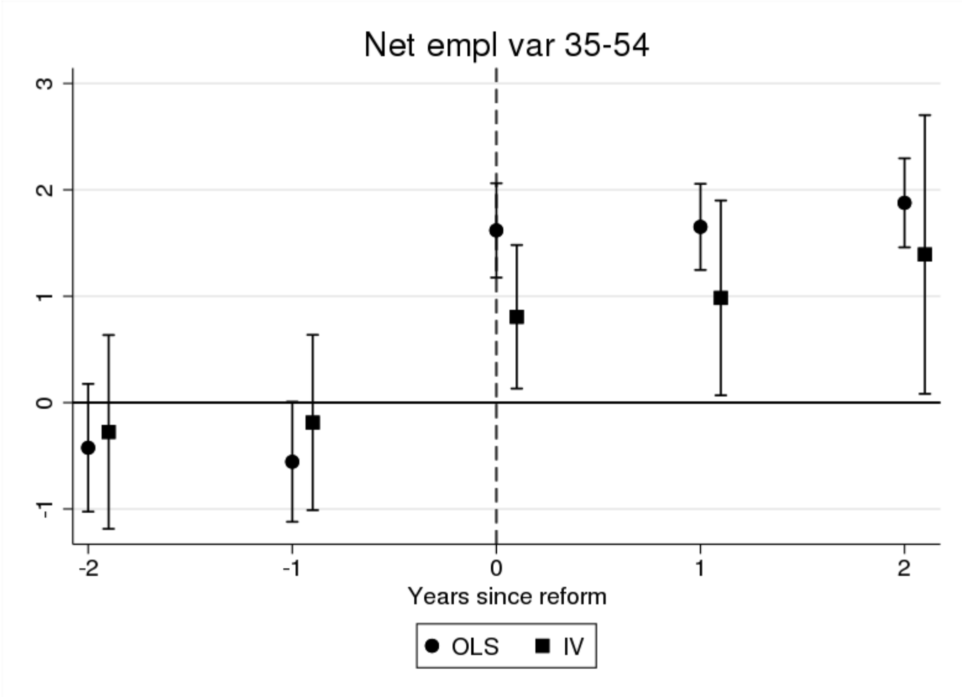
Notes: Estimates of equation 3 on INPS data, see Section 7.1 for details. First stage statistics for the IV estimates are reported in Table 1. Point estimates and 95% confidence intervals.

Figure A6: **Estimated cumulative effects**



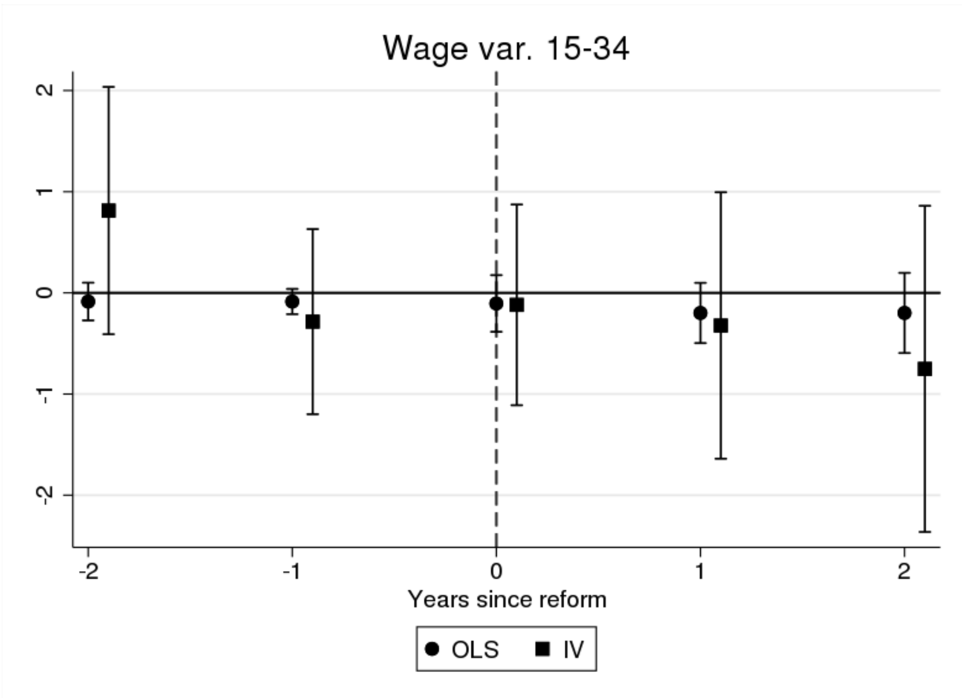
Notes: Estimates of equation 3 on INPS data, see Section 7.1 for details. First stage statistics for the IV estimates are reported in Table 1. Point estimates and 95% confidence intervals.

Figure A7: **Estimated cumulative effects**



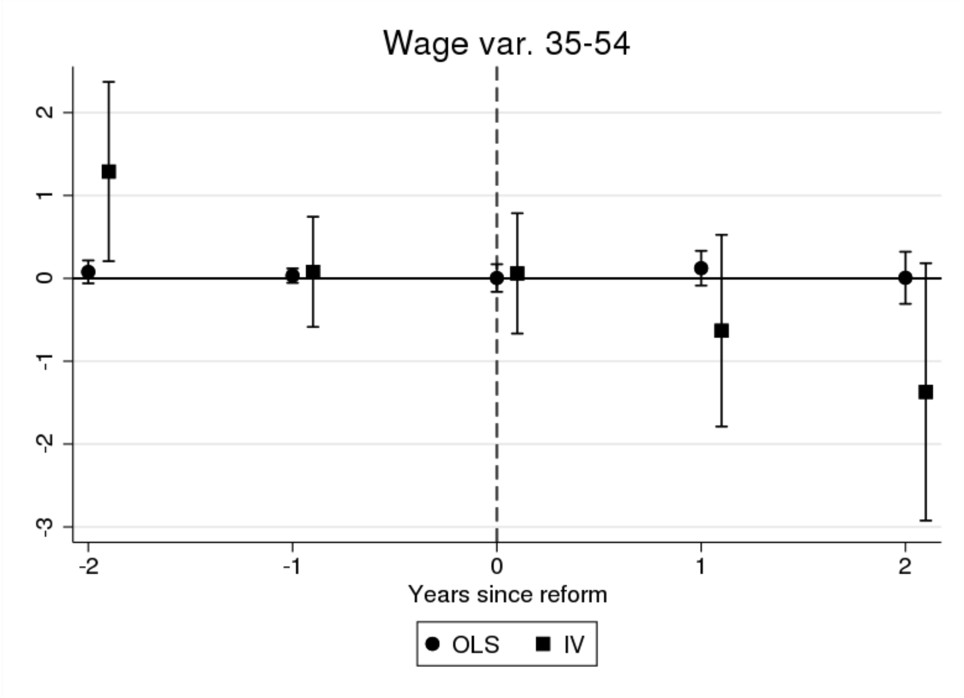
Notes: Estimates of equation 3 on INPS data, see Section 7.1 for details. First stage statistics for the IV estimates are reported in Table 1. Point estimates and 95% confidence intervals.

Figure A8: **Estimated cumulative effects**



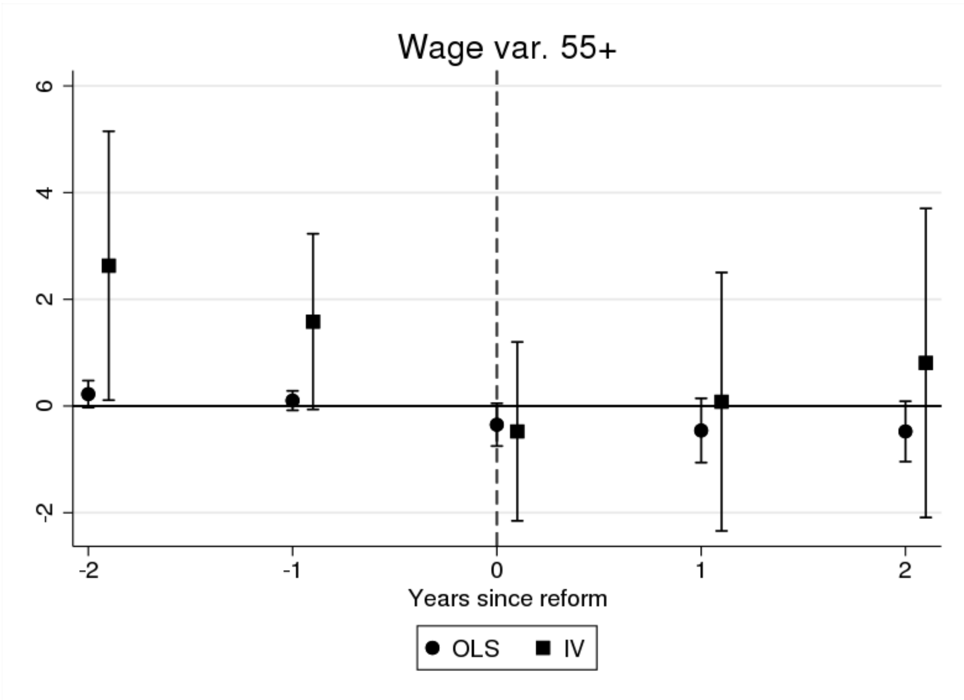
Notes: Estimates of equation 3 on INPS data, see Section 7.1 for details. First stage statistics for the IV estimates are reported in Table 1. Point estimates and 95% confidence intervals.

Figure A9: **Estimated cumulative effects**



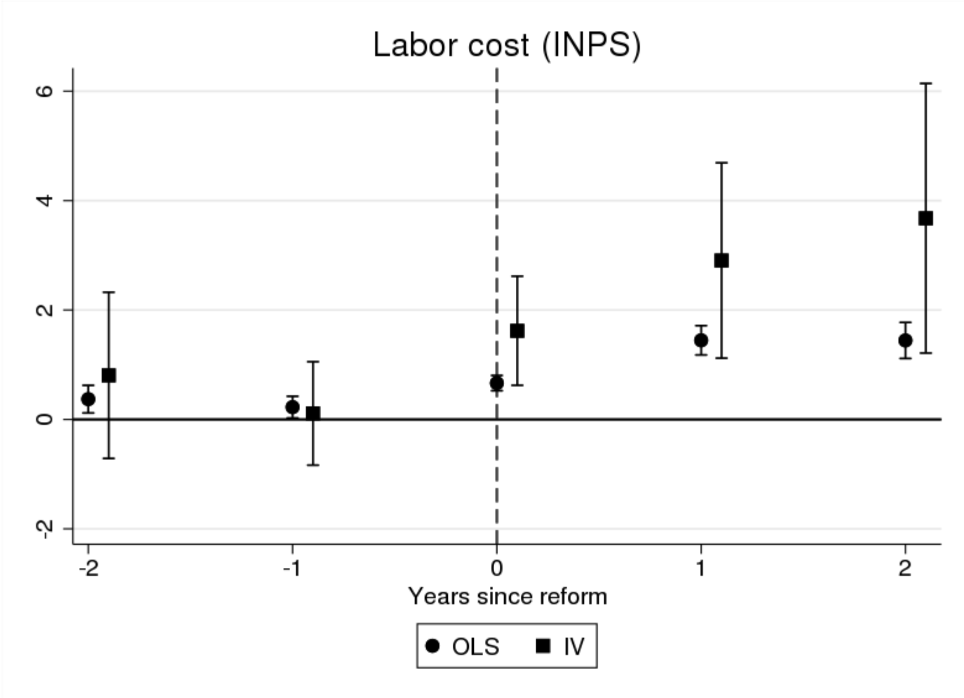
Notes: Estimates of equation 3 on INPS data, see Section 7.1 for details. First stage statistics for the IV estimates are reported in Table 1. Point estimates and 95% confidence intervals.

Figure A10: **Estimated cumulative effects**



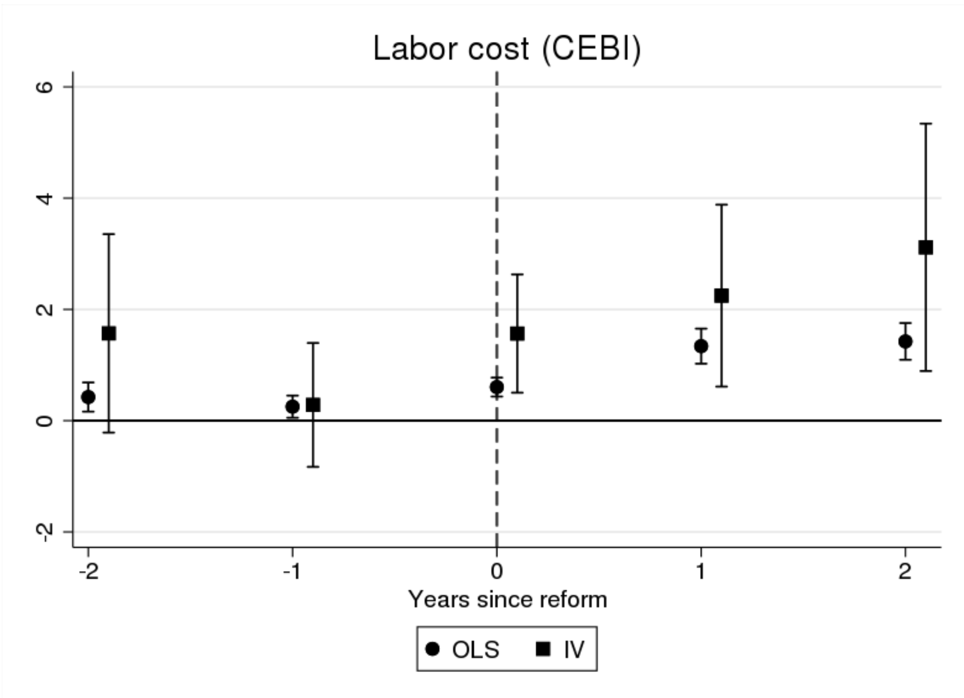
Notes: Estimates of equation 3 on INPS data, see Section 7.1 for details. First stage statistics for the IV estimates are reported in Table 1. Point estimates and 95% confidence intervals.

Figure A11: **Estimated cumulative effects**



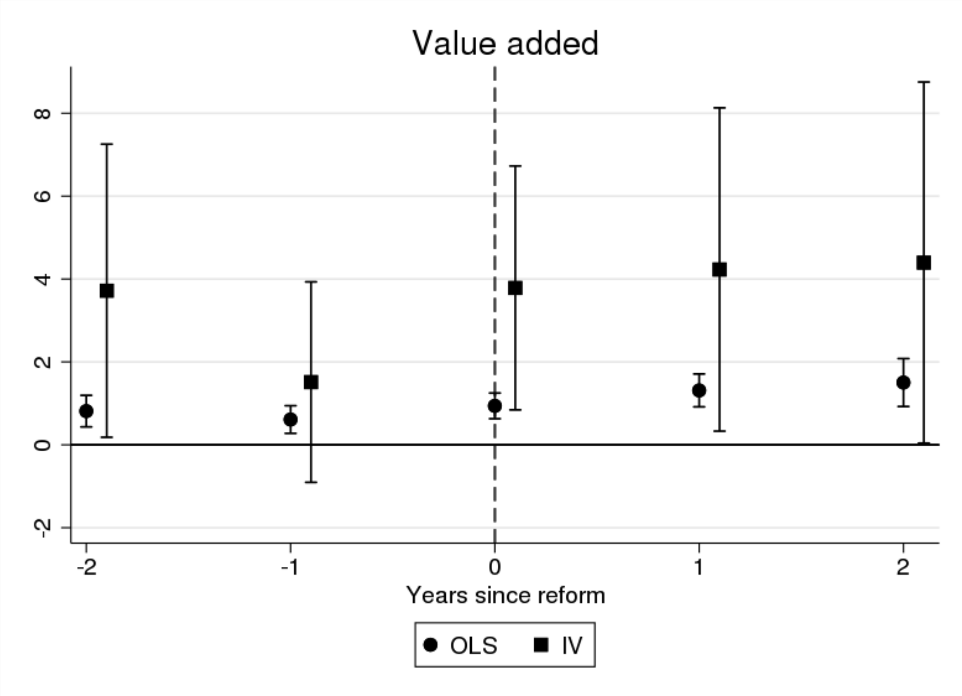
Notes: Estimates of equation 3 on INPS data, see Section 7.1 for details. First stage statistics for the IV estimates are reported in Table 1. Point estimates and 95% confidence intervals.

Figure A12: **Estimated cumulative effects**



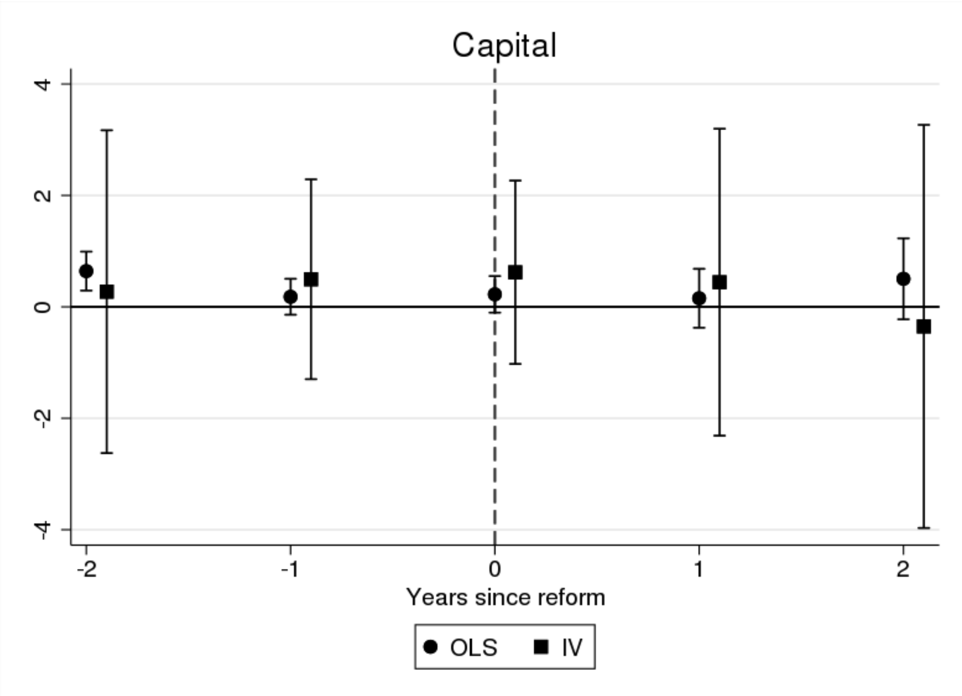
Notes: Estimates of equation 3 on INPS data, see Section 7.1 for details. First stage statistics for the IV estimates are reported in Table 1. Point estimates and 95% confidence intervals.

Figure A13: **Estimated cumulative effects**



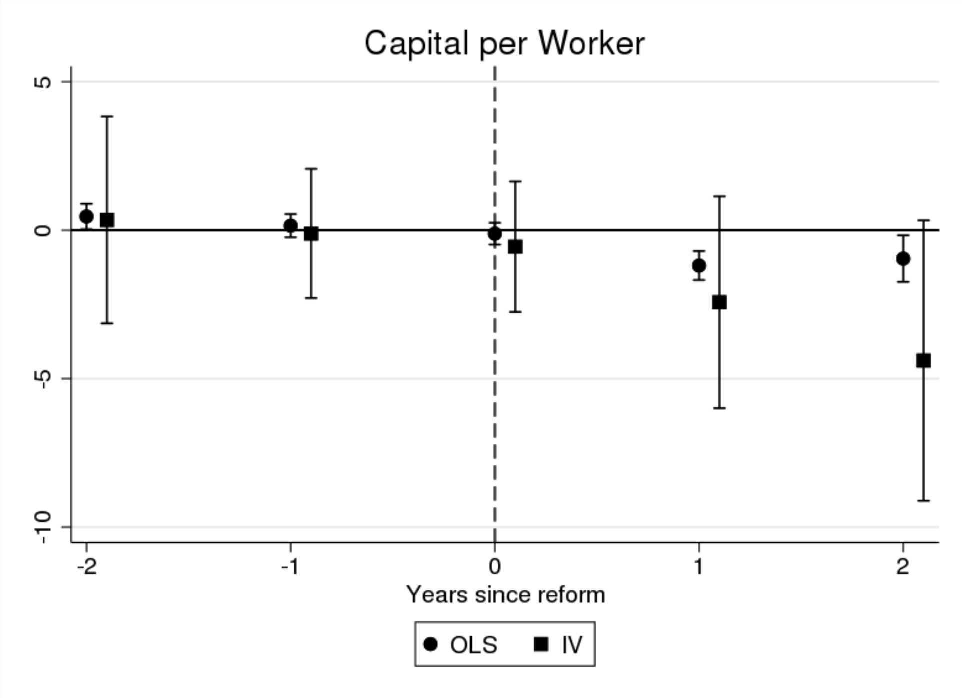
Notes: Estimates of equation 3 on INPS data, see Section 7.1 for details. First stage statistics for the IV estimates are reported in Table 1. Point estimates and 95% confidence intervals.

Figure A14: **Estimated cumulative effects**



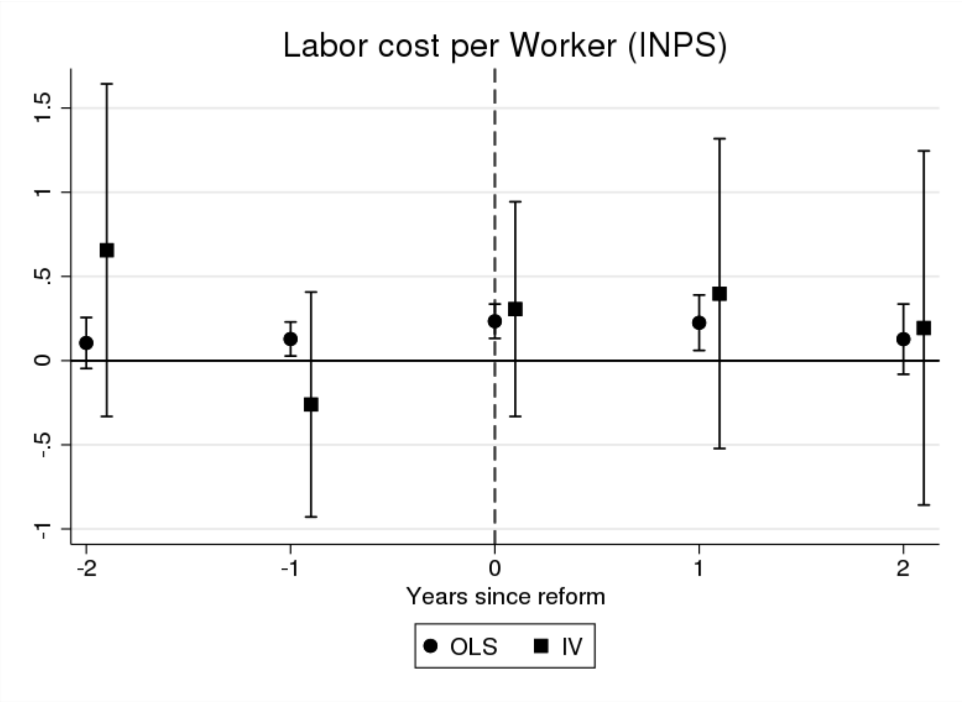
Notes: Estimates of equation 3 on INPS data, see Section 7.1 for details. First stage statistics for the IV estimates are reported in Table 1. Point estimates and 95% confidence intervals.

Figure A15: **Estimated cumulative effects**



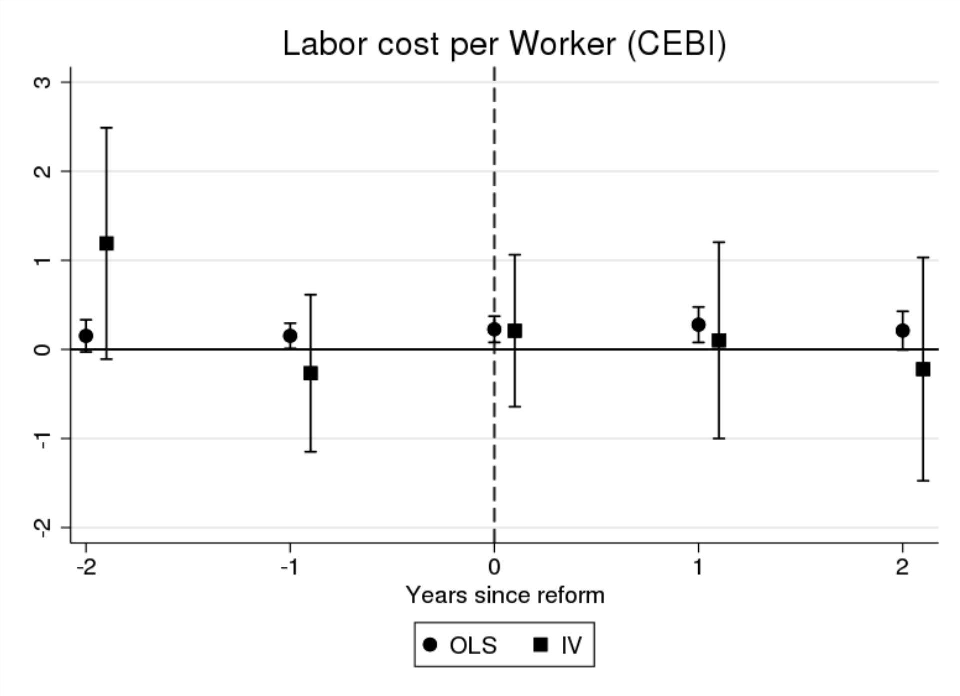
Notes: Estimates of equation 3 on INPS data, see Section 7.1 for details. First stage statistics for the IV estimates are reported in Table 1. Point estimates and 95% confidence intervals.

Figure A16: **Estimated cumulative effects**



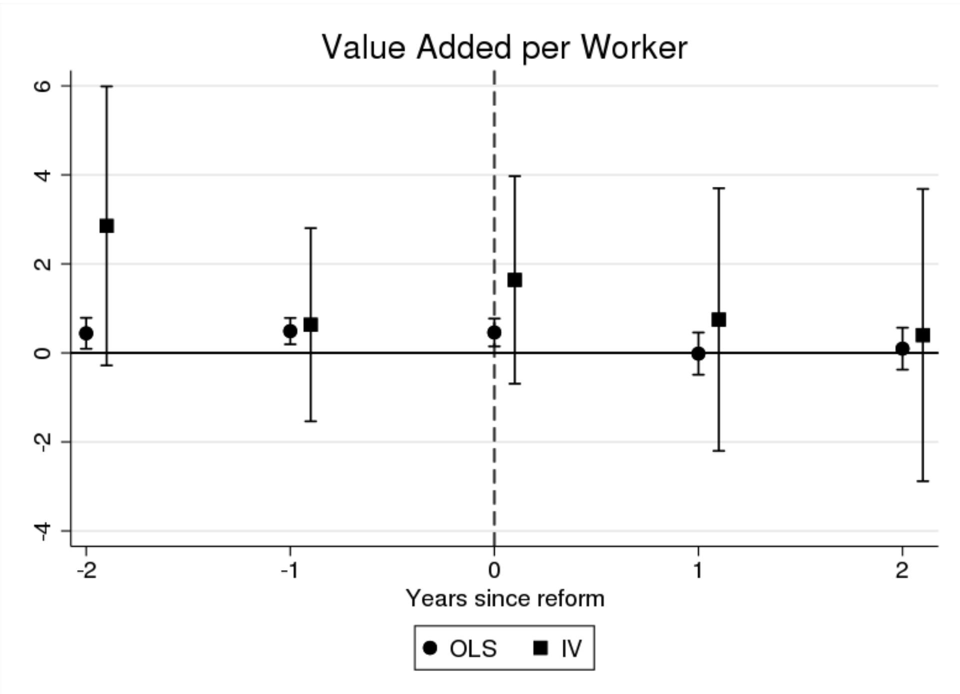
Notes: Estimates of equation 3 on INPS data, see Section 7.1 for details. First stage statistics for the IV estimates are reported in Table 1. Point estimates and 95% confidence intervals.

Figure A17: **Estimated cumulative effects**



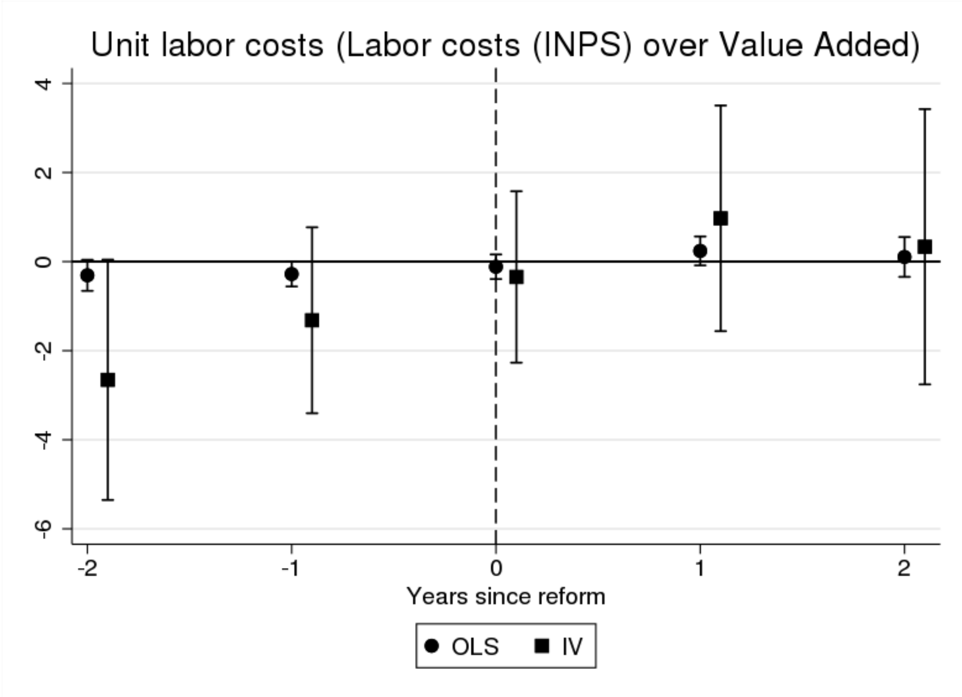
Notes: Estimates of equation 3 on INPS data, see Section 7.1 for details. First stage statistics for the IV estimates are reported in Table 1. Point estimates and 95% confidence intervals.

Figure A18: **Estimated cumulative effects**



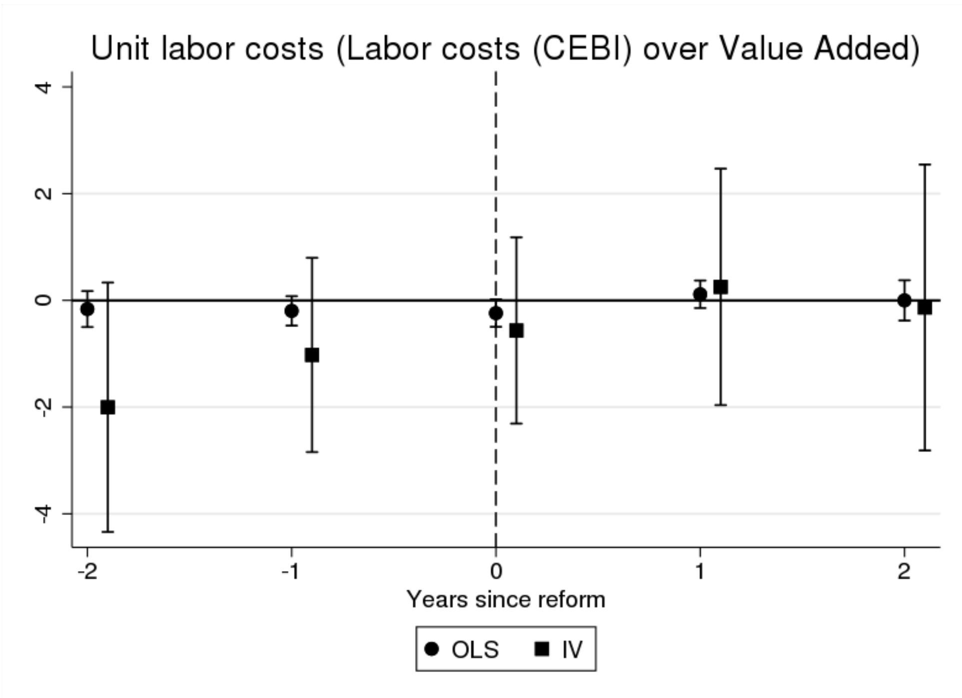
Notes: Estimates of equation 3 on INPS data, see Section 7.1 for details. First stage statistics for the IV estimates are reported in Table 1. Point estimates and 95% confidence intervals.

Figure A19: **Estimated cumulative effects**



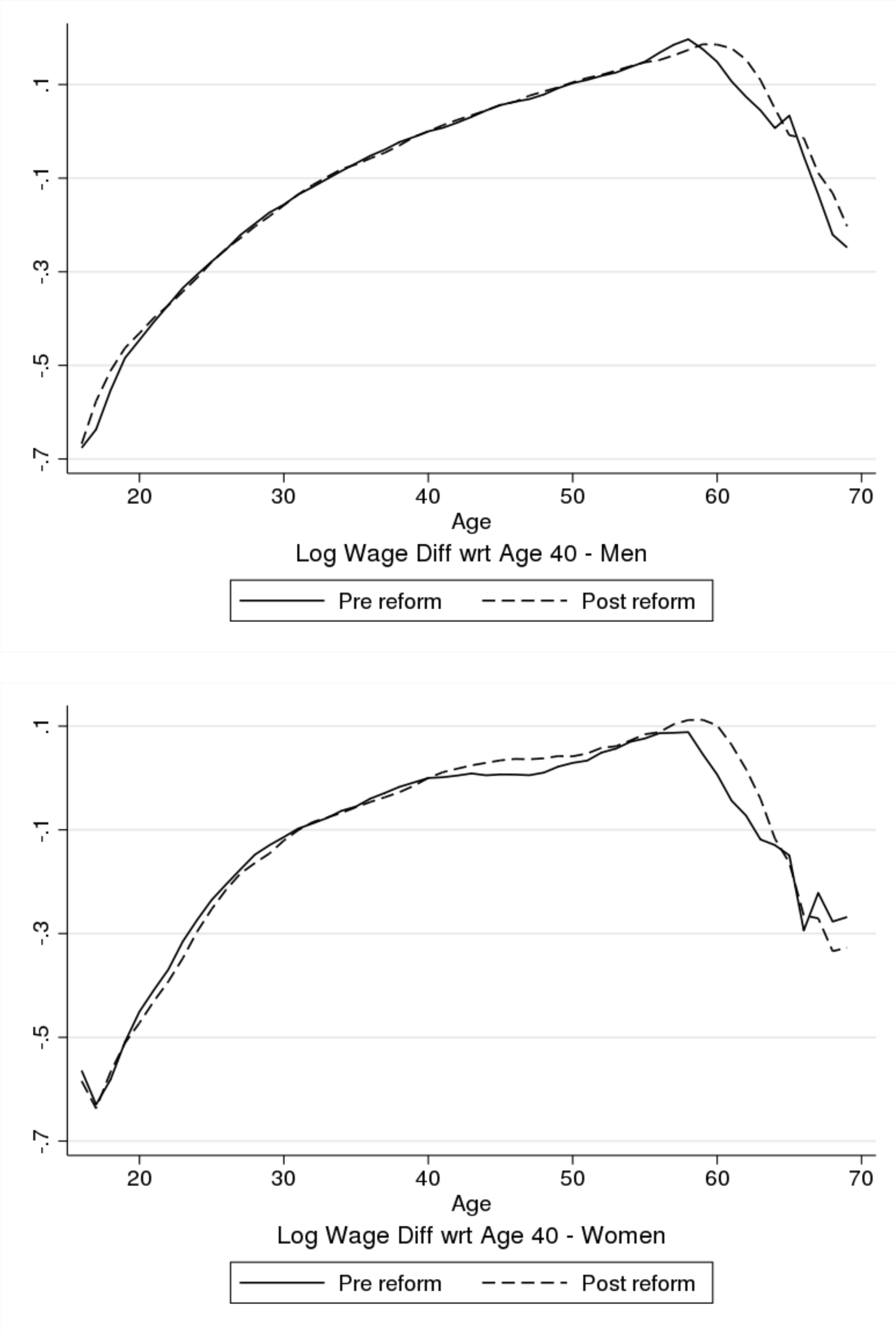
Notes: Estimates of equation 3 on INPS data, see Section 7.1 for details. First stage statistics for the IV estimates are reported in Table 1. Point estimates and 95% confidence intervals.

Figure A20: **Estimated cumulative effects**



Notes: Estimates of equation 3 on INPS data, see Section 7.1 for details. First stage statistics for the IV estimates are reported in Table 1. Point estimates and 95% confidence intervals.

Figure A21: **The wage-age gradient for all workers in the overall economy**



Notes: Our calculations on INPS data. Data cover the whole private non agricultural sector; only employees working at least 150 days in a given year are included. Each wage level is normalized to the average for 40-44 years old in each year.

Table A1: **Literature review: estimates of the effects of aging workforce on firm outcomes**

Authors	Data	Outcome	Old (y.o.)	Empirical Strategy	Instrumental variable	Effect
Daveri and Maliranta (2007)	Finland, electronics, forest, ind. machinery 1990-2002	Value added per hour worked, gross wage, TFP index	Dep. var.: age	FE, IV controls for experience and seniority	Lagged values for experience and seniority	Limited eff. of age on prod., larger on wage; seniority and exp matter more; prod/pay gap ↑ in electronics; no eff in traditional industries
Malmberg et al. (2008)	Sweden, manufacturing and mining 1985-1996 Avg. firm size: 80	Value added per worker	50+	FE (dev. from the mean) IV (for avg. age)	Lagged values of age shares	Slightly positive eff on VA p.w. in larger firms (50+)
Martins et al. (2009)	Portugal non-farm priv. sector, 1992-1997 Avg. firm size: <100	Hirings, separations, net job creation, of women, sales	57-60	DD+matching (age*time)	Pension reform stricter elig. requirements for women	Hirings and separations ↓ no eff. on net job creation negative eff on sales no in p.w. terms
Van Ours and Stoeldraijer (2011)	Netherlands, manufacturing 2000-2005 Avg. firm size: 97 (FTE: 77)	Value added, labor costs per FTE	50-56, 57+	FE, FD, GMM	Lagged values of age shares	Slightly positive eff. on prod. and wage no prod./pay gap
Cardoso et al. (2011)	Portugal, manuf. and service (priv. sect) 1986-2008 Empl(log): 3.2	Sales, labor costs p.w.	50-54, 55+	FD-IV-GMM	Lagged values of age shares	No negative eff. on sales and wage, no prod/ pay gap
Dostie (2011)	Canada, economy, no agric. 1999-2005 Avg. firm size: 15	Value added, avg. wage	55+	Two-stage estimation	Inverted demand funct for capital as proxy for prod. shock	No negative eff. on prod and wage, no prod/ pay gap Heterogeneity by gender (<0 men with degree)

Authors	Data	Outcome	Old (y.o.)	Empirical Strategy	Instrumental variable	Effect
Cataldi et al. (2012)	Belgium, private sector 1999-2006 Avg. firm size: 100	Value added per hour worked, gross hourly wage	50+ (changes in work hours)	Pooled OLS, FD	Lagged values of age shares	Negative eff. on prod, positive on avg. wage (ref. group: prime-aged) prod./pay gap ↑ with age
Göbel and Zwick (2012)	Germany, manuf. and services 1997-2005 Avg. firm size: 176 (FTE)	Value added p.w. (sales-interm. inputs)	50-54, 55-60	Pooled OLS, dynamic GMM (controls for experience and seniority)	Lagged values of age shares	No negative eff. on prod. (ref. group: 35-40 y.o.) No sectoral diff
Mahlberg et al. (2013)	Austria, private sector (no agric.) 2002-2005 Avg. firm size: 70	Value added p.w., average wage	49+	OLS with lagged regressors, FE, RE, GMM	Lagged values of age shares	No effect on VA p.w. and avg. wage; negative eff. on avg. wage of the share of younger workers ($\leq$ 29) (ref. group: prime-aged)
Vandenberghe (2013)[a]	Belgium, priv. sector 1998-2006 Empl(log): 3.9	Value added, labor costs, gross profits p.w.	50-64 men and women	FD-IV-GMM Two-stage estimation	Lagged values of age shares, interm. goods as proxy for prod. shock	Larger negative eff. on prod. than wage of older women, negative eff. on profits (ref. group: 30-49 men) Larger eff. in services and large firms
Ilmakunnas and Ilmakunnas (2015)	Finland, priv. non farm buss. sector 1994-1998	Hirings of old workers	49-57	DDD (age*size*time)	Pension reform stricter elig. requirements	Hirings increase mostly for 51-52 y.o., more strongly in larger firms

[a] The author claims that the observed increase in the share of older women is more likely to be exogenous than that in the share of older men since driven by the alignment of the legal retirement age of women to that of men. Thus, this provides a sort of "natural experiment".

Authors	Data	Outcome	Old (y.o.)	Empirical Strategy	Instrumental variable	Effect
Boeri et al. (2017)	Italy, priv. sector 2008-2014 15-150 empl.	Net empl. variation by age	55+	DD	Pension reform ind. and firm treatment	Negative effects on young workers (less than 30)
Bovini and Paradisi (2019)	Italy, priv. sector 2009-2015 3-200 empl.	Hirings and firings by age class	55+	DD	Pension reform ind. and firm treatment	Subst. between workers of different ages
Hut (2019)	Netherlands, priv. non fin sector 2001-2018 5+ empl.	Empl. by age profits, labour costs, inv.	54-57	DD (year of bith)	Pension reform ind. and firm treatment	Negative effects on financially constrained firms

Table A2: **Descriptive statistics**

UNBALANCED PANEL

Variable	Obs	Mean	Std. Dev.	Min	Max
Total employees	9,654	9654.0	608.9	3732.4	20.0
Employment share (15-34, p.c.)	9,654	23.4	13.7	0	90.6
Employment share (35-54, p.c.)	9,654	65.0	11.6	9.4	100
Employment share (55+, p.c.)	9,654	11.6	7.5	0	79.3
Net employment variation (15-34, p.c.)	9,654	1.1	5.2	-36.3	306.5
Net employment variation (35-54, p.c.)	9,654	0.0	9.0	-100.0	420.3
Net employment variation (55+, p.c.)	9,654	-1.1	2.3	-28.7	50.8
FTE Wage (15-34, euros)	9,616	87.8	18.2	53.7	148.5
FTE Wage (35-54, euros)	9,654	110.1	29.6	58.5	216.5
FTE Wage (55+, euros)	9,579	132.2	51.3	54.3	338.2
Wage var (15-34, p.c.)	9,609	2.0	5.7	-15.8	20.2
Wage var (35-54, p.c.)	9,654	1.7	4.5	-11.7	17.0
Wage var (55+, p.c.)	9,538	2.2	11.7	-28.7	47.0
Capital (euros*1000)	9,654	113691.1	1261317	3	57200000
Capital var. (p.c.)	9,579	-0.8	11.7	-22.7	25.6
Total labor costs (euro*1000)	9,654	18435.4	100517.6	20.9	3507677.0
Total labor costs var. (p.c.)	9,579	2.2	7.7	-10.4	21.1
Value added (euro*1000)	9,654	44863.7	314858.9	-453461.0	12000000.0
Value added var (p.c.)	9,579	1.7	16.5	-27.3	30.8

BALANCED PANEL

Variable	Obs	Mean	Std. Dev.	Min	Max
Total employees	5,125	691.2092	4678.207	21	140687
Employment share (15-34, p.c.)	5,125	22.9	13.3	0	90.6
Employment share (35-54, p.c.)	5,125	65.3	11.3	9.4	98.1
Employment share (55+, p.c.)	5,125	11.8	7.5	0	79.3
Net employment variation (15-34, p.c.)	5,125	1.0	3.7	-36.3	66.7
Net employment variation (35-54, p.c.)	5,125	0.1	5.8	-63.6	90.4
Net employment variation (55+, p.c.)	5,125	-1.1	2.0	-24.5	25.5
FTE Wage (15-34, euros)	5,116	88.24434	18.05651	53.65068	148.462
FTE Wage (35-54, euros)	5,125	110.4067	29.14231	58.53726	216.4977
FTE Wage (55+, euros)	5,102	133.2559	51.27009	54.32445	338.2433
Wage var (15-34, p.c.)	5,113	2.1	5.6	-15.8	20.2
Wage var (35-54, p.c.)	5,125	1.8	4.3	-11.7	17.0
Wage var (55+, p.c.)	5,088	2.3	11.4	-28.7	47.0
Capital (euros*1000)	5,125	82330.73	418256.8	25	9053672
Capital var. (p.c.)	5,116	-0.4	11.4	-22.7	25.6
Total labor costs (euro*1000)	5,125	20679.73	119983.3	407.049	3507677
Total labor costs var. (p.c.)	5,116	2.3	7.3	-10.4	21.1
Value added (euro*1000)	5,125	46594.1	261139	-453461	7683976
Value added var (p.c.)	5,116	2.3	16.1	-27.3	30.8

Notes: INVIND-INPS-CEBI data. Years: 2010-2014, selected sample: firms that employed at least 50 employees in the year they first appeared in the sample; firms which are sampled in each of the five years and do not have missing values on variables such as capital, labor costs and value added.

Table A3: **Requirements for old age pension eligibility; changes in rules according to the law in place at time t and the law known at $t-1$ for time t.**

	$Law_{t\|t}$		$Law_{t\|t-1}$		$Law_{t\|t} - Law_{t\|t-1}$	
	Men	Women	Men	Women	Men	Women
Year t						
2009	65	60	65	60	0	0
2010	65	60	65	60	0	0
2011	65	60	65	60	0	0
2012	66	62	65	60	1	2
2013	66.3	62.3	66.3	62.3	0	0
2014	66.3	63.8	66.3	63.8	0	0
2015	66.3	63.8	66.3	63.8	0	0
2016	66.6	65.6	66.6	65.6	0	0
2017	66.6	65.6	66.6	65.6	0	0

Notes: Old age pension eligibility requires the legal retirement age (reported in the Table) and at least 20 accrued years of social security contribution. We incorporate the 1-year waiting window (the number of months between retirement eligibility and actual pension disbursement) in the provision of statutory retirement age.

Table A4: **Requirements for seniority pension eligibility; changes in rules according to the law in place at time t and the law known at $t-1$ for time t.**

	$Law_{t\|t}$			$Law_{t\|t-1}$			$Law_{t\|t} - Law_{t\|t-1}$		
	Quota	only C		Quota	only C		Quota	only C	
	A, Q, $C \geq 35$	Men	Women	A, Q, $C \geq 35$	Men	Women	A	Men	Women
Year t									
2009	59, 95	40	40	59, 95	40	40	0	0	0
2010	59, 95	40	40	59, 95	40	40	0	0	0
2011	60, 96	40	40	60, 96	40	40	0	0	0
2012	-	42.1	41.1	60, 96	40	40	-	2.1	1.1
2013	-	42.4	41.4	-	42.4	41.4	-	0	0
2014	-	42.5	41.5	-	42.5	41.5	-	0	0
2015	-	42.5	41.5	-	42.5	41.5	-	0	0
2016	-	42.8	41.8	-	42.8	41.8	-	0	0
2017	-	42.8	41.8	-	42.8	41.8	-	0	0

Notes: A stands for age, C for number of years of social security contribution. Quota= $A+C$ is the sum of age and years of social security contribution, which must be larger or equal than Q to reach retirement eligibility. Also requirements on minimum retirement age (A) and accrued years of contribution (C) are binding. Alternatively, retirement eligibility is also granted when the number of accrued years of social security contribution is higher than a minimum amount (i.e. 39 in 2007, 40 in 2008). We incorporate the 1-year waiting window (the number of months between retirement eligibility and actual pension disbursement) in the provision of statutory retirement age.

Table A5: **Wages var net of composition effects**

	Wages		
VARIABLES	15-34	35-54	55+
FD OLS	-0.126	0.175	-1.507*
Net empl var 55+	(0.164)	(0.387)	(0.859)
	5113	5125	5088
Obs.			
FD OLS with firm FE			
Net empl var 55+	-0.109	0.301	-2.203**
	(0.190)	(0.449)	(0.912)
Obs.	5113	5125	5088
FD (Years 2011-12)			
	-0.0651	0.511	-3.044*
	(0.450)	(0.827)	(1.764)
	1022	1025	1020
FD IV (Years 2011-12)			
Net empl var 55+	-2.903	-3.345	-14.36
	(1.998)	(2.814)	(10.28)
Obs.	1022	1025	1020

Notes: Estimates of equation 3. All regressions include sector and year fixed effects and the 2010 shares of 35-54 and 55+ workers. Standard errors in brackets clustered at the firm level.
* significant at 10%; ** significant at 5%; *** significant at 1%.

Table A6: **Check for attrition: sample entry and exit**

Column	1	2
VARIABLES	Exit	Entry
FD OLS		
Net empl var 55+	-0.034	0.211
	(0.026)	(0.156)
FD OLS with FE		
Net empl var 55+	-0.0196	0.00915
	(0.020)	(0.144)
Obs	13.176	13.176

Notes: Estimates of equation 3. All regressions include sector and year fixed effects and the 2010 shares of 35-54 and 55+ workers. Standard errors in brackets clustered at the firm level.
* significant at 10%; ** significant at 5%; *** significant at 1%.

Table A7: **Variation in part time shares**

	15-34	35-54	55+
FD OLS	0.078*	0.044	0.098**
Net empl var 55+	(0.043)	(0.045)	(0.048)
	5113	5125	5088
Obs			
FD OLS with FE	0.107**	0.046	0.119**
Net empl var 55+	(0.050)	(0.047)	(0.059)
	5113	5125	5088
Obs			
FD OLS (Years 2011-12)	-0.021	-0.049	0.183**
	(0.105)	(0.034)	(0.081)
	1022	1025	1020
Obs			
FD IV (Years 2011-12)	-0.225	0.080	1.451*
Net empl var 55+	(0.743)	(0.248)	(0.835)
Obs	1022	1025	1020

Notes: Estimates of equation 3. All regressions include sector and year fixed effects and the 2010 shares of 35-54 and 55+ workers. Standard errors in brackets clustered at the firm level.
* significant at 10%; ** significant at 5%; *** significant at 1%.

Table A8: **Main results obtained on an alternative INPS dataset: years 2012-11**

		Unbalanced sample								
		All firms			Firms less than 50 empl			Firms with 50 or more empl		
		Coef	Se	Obs	Coef	Se	Obs	Coef	Se	Obs
Net empl var	15-34	0.943***	(0.069)	1489856	0.747***	(0.093)	1423957	1.132***	(0.145)	65899
FTE wage var	15-34	-0.021***	(0.004)	937185	-0.023***	(0.003)	875306	-0.018***	(0.001)	61879
Net empl var	35-54	2.005***	(0.115)	1489856	1.065***	(0.105)	1423957	2.911**	(0.433)	65899
FTE wage var	35-54	-0.020***	(0.007)	1023882	-0.038***	(0.003)	959191	-0.010	(0.006)	64691
FTE wage var	55+	0.003	(0.006)	354967	0.025***	(0.006)	299619	-0.032***	(0.007)	55348
Capital		0.070***	(0.017)	411229	0.143***	(0.012)	360730	0.004	(0.023)	50499
Labor costs	INPS	0.347***	(0.073)	1395833	0.644***	(0.027)	1330496	0.047**	(0.017)	65337
Labor costs	Balance sheet	0.242***	(0.035)	416343	0.470***	(0.0122)	365660	0.075***	(0.015)	50683
Value added		0.152***	(0.021)	415812	0.277**	(0.00866)	465220	0.058***	(0.012)	50592

Notes: Estimates of equation 3 on the who paid Social Security Contributions for at least one day in the relevant year. Regressions include as additional controls: the share of 35-54 and 55+ workers in 2010, sector and year fixed effects. Standard errors in brackets clustered at the firm level.

* significant at 10%; ** significant at 5%; *** significant at 1%.

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