# Countries for Old Men: An Analysis of the Age Wage Gap*

Nicola Bianchi Matteo Paradisi

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**Abstract**

Drawing on extensive administrative and survey data, this study illustrates the growing wage disparity between older and younger workers in high-income countries. Our analysis pinpoints negative career spillovers as the driving factor, as an increasing number of older workers, a higher retirement age, and constraints on firms' ability to create higher-ranked positions restrict younger workers' access to higher-paying roles. As older workers enjoy lengthier, successful careers, younger workers face lower initial wages, slower career progression, more frequent turnover with lesser financial gains, and decreased likelihood of working for higher-paying firms. We conclude by connecting these outcomes to other labor-market trends.

JEL Classification: J31, J21, M51, J11.
Keywords: wage growth, age wage gap, career spillovers, older workers, labor-market entry.

*Contact information: Nicola Bianchi, Kellogg School of Management, Northwestern University, and NBER, 2211 Campus Drive, 60201 Evanston IL, nicola.bianchi@kellogg.northwestern.edu; Matteo Paradisi, EIEF, via Sallustiana 62, 00187 Rome, matteo.paradisi@eief.it. We thank Jaime Arellano-Bover, Alexander Bartik, Barbara Biasi, Christian Dustmann, Andrew Garin, Luigi Guiso, Ben Jones, Hyejin Ku, Salvatore Lattanzio, Attila Lindner, Sara Moreira, Paolo Naticchioni, Raffaele Saggio, Uta Schoenberg, as well as participants at various seminars and conferences for helpful comments. We thank Sean Chen, Alessandra Grimaldi, Chuqiao Nan, and Georgii Zherebilov for outstanding research assistance. The realization of the present article was possible thanks to the sponsorship and financial support to the "VisitINPS Scholars" program. This study uses the Cross-sectional model of the Linked-Employer-Employee Data (LIAB) (Version 2, Years 1993-2017) from the IAB. Data access was provided via on-site use at the Research Data Centre (FDZ) of the German Federal Employment Agency (BA) at the Institute for Employment Research (IAB) in Berlin and subsequently via remote data access (project number: fdz1968/1969).

# 1 Introduction

The workforce in many high-income countries is aging rapidly. In the United States, for example, the share of workers aged 55 or older increased by 88 percent, from 12.9 percent in 1985 to 24.3 percent in 2020, marking the largest growth among all age groups.[1] This demographic shift starkly contrasts with the one that took place after World War II. In the second half of the 1960s, the entry of the "baby-boom" cohort into the labor market led to a steep decline in the average worker age, coinciding with a slowdown in the growth of younger workers' wages. Prior studies (Welch, 1979; Freeman, 1979) have attributed these wage dynamics to the increased supply of younger workers under the assumption of imperfect substitutability between younger and older workers.

If we applied the same economic thinking to the current aging workforce, we would expect older workers to experience a reduction in their preexisting wage advantage over younger workers. Instead, the current aging trend has coincided with an expanding *age wage gap*. For example, the wage gap between workers over 55 and those under 35 increased by 61 percent in the United States between 1979 and 2018 and by 96 percent in Italy between 1985 and 2019.

This paper seeks to reconcile the apparent conflict between the widening age wage gap and the aging of the workforce. It uses matched employer-employee administrative data from Italy and Germany with 347 million observations on 38 million workers across 3.7 million firms, along with survey data on 6.6 million workers from the Luxembourg Income Study for fourteen high-income countries. Our analysis of these extensive data emphasizes the role of negative career spillovers (Bianchi et al., 2023).[2]

In a frictional labor market, characterized by costly worker-firm separations and firm-level constraints on adding higher-ranked positions, improved career outcomes for older workers can come at the expense of younger workers' career progression.[3] The growing population of older workers and their longer careers have allowed them to accrue more seniority, and thereby to progress further along organizational hierarchies and to occupy more higher-ranked positions for longer periods. These trends, together with declining economic growth, have made it more difficult for firms to make room at the top of their hierarchies for younger

[1] https://bit.ly/3eQmakN.

[2] In the rest of the introduction, we will usually focus on the results obtained using the Italian dataset because it is the most comprehensive and the only one that allows us to perform the full spectrum of tests included in this paper.

[3] Costly worker-firm separations can, for example, arise from knowledge spillovers (Cornelissen, Dustmann, and Schönberg, 2023), backloaded wages (Ke, Li, and Powell, 2018), or firm-specific human capital (Gathmann and Schönberg, 2010). Firm-level constraints on adding higher-ranked positions can stem from dwindling labor productivity and GDP growth (Syverson, 2017).

workers, who have experienced longer waiting times for promotions and slower career progression.

We highlight six main findings underscoring the importance of negative career spillovers. First, the widening age wage gap predominantly results from younger workers' increasing struggles to reach the upper segments of the wage distribution, a contrast to the trend experienced by older workers. In Italy, the likelihood of workers under 35 belonging to the top quartile of weekly wages declined by 34 percent from 1985 to 2019, while the probability for those over 55 increased by 32 percent. Moreover, the share of managerial roles held by under-35 workers fell from 8 percent to 3 percent, while that held by over-55 workers rose from 12 percent to 28 percent.

Second, we propose a decomposition of the growth in the age wage gap to quantify the impact of the divergent career trajectories of younger and older workers.[4] We identify two key components: the *rank gap* and the *distributional gap*. The rank (or positional) gap, a direct implication of negative career spillovers, represents the portion of the age wage gap's expansion that is attributable to older workers surpassing younger workers in the wage distribution. The distributional gap, capturing broader changes to the support of the wage distribution (for example, those caused by higher wage inequality), indicates that the age wage gap has expanded due to faster wage growth in segments of the wage distribution with a higher share of older workers, thereby amplifying their preexisting wage advantage. The rank gap was the primary factor driving the widening of the age wage gap in nearly all countries in our sample. For example, it accounted for 78 percent of the total growth in Italy, 89 percent in the United States, 56 percent in Germany, and 77 percent in Canada.

Third, younger workers' careers have deteriorated both at and after labor-market entry. Consistent with the increased concentration of older workers in higher-paying jobs, new entrants have progressively started lower in the wage distribution, and have experienced slower wage growth for several years after entry. This analysis focuses on the *rank (or positional) loss* experienced by under-35 workers, which isolates variations in log wages stemming from shifts in under-35 workers' shares across vigintiles of the wage distribution, while keeping the support of the distribution itself fixed at baseline. In Italy, 86 percent of the total rank loss originates from a lower initial rank, while the remaining 14 percent arises from sluggish post-entry rank growth.

Fourth, in line with the existence of negative career spillovers, younger workers have incurred positional losses in the wage distribution within both lower-paying and higher-paying firms. In contrast, older workers have experienced large positional gains in all firms except those at the very top of the distribution of average firm wages. Within these higher-

[4] Bayer and Charles (2018) performs a similar decomposition for the racial earning gap in the United States.

paying firms, the concentration of older workers has increased disproportionately, negatively affecting the mean wage rank of all workers. For example, within firms in the top 5 percent of the distribution of mean wages in Italy, the share of over-55 workers increased by 28 percent between 1985 and 2019 (from 6 percent to 7.7 percent), while their wage rank declined by 0.33 log points. However, even within these higher-paying firms with extreme congestion, younger workers have sustained larger positional losses. Therefore, the age wage gap has widened within all firms, regardless of their mean pay level.

Rather than stemming from turnover events, the increased concentration of older workers within higher-paying firms originates from the fact that they were more likely to hold onto their positions in these firms. Compared to lower-paying firms, the mean age of over-55 workers in firms paying above-median wages increased by an additional 58 percent (+9 months vs. +5.7 months) from 1985 to 2019, and their mean tenure in 2019 was 61 percent higher (12.7 years vs. 7.9 years). Lower firm dynamism may have contributed to this trend by making jobs in higher-paying firms disappear at progressively lower rates (Decker et al., 2014).

Fifth, the entrenchment of older workers in higher-paying firms has decreased the probability of younger workers securing employment in these firms. Confined to lower-paying firms and facing slower career progression, younger workers have increasingly relied on turnover for career advancement. In Italy, the share of under-35 workers experiencing a turnover event rose from 27 percent in 1985 to 44 percent in 2019. However, in line with increased congestion in higher-paying jobs and firms, younger workers' financial gains from firm-to-firm transitions have decreased. The average wage percentile increase associated with under-35 workers' turnover events declined by 34 percent, while the median gain fell by 67 percent.

Sixth, in line with the notion of negative career spillovers, the widening of the age wage gap has been significantly larger among firms with more limited opportunities to add higher-ranked positions to their organizational hierarchies. Older, larger firms with lower employment growth have found it particularly challenging to map out satisfactory career trajectories for younger workers. In Italy, for instance, the age wage gap rose by 0.24 log points among firms with below-median employment growth and by 0.17 log points among firms with above-median employment growth. This difference, equal to 38 percent of the increase in the average age wage gap, is large in magnitude and statistically significant at 1 percent.

Finally, the paper examines other mechanisms that could account for the expanding age wage gap, despite an aging workforce: wage inequality, higher returns to experience and higher-level skills, changes in the composition of younger and older workers, and sectoral and occupational shifts. Overall, our analysis suggests that these factors are not fully compatible with the characteristics of the growth in the age wage gap.

For example, higher returns to experience and higher-level skills should have made the wages of older, more experienced workers grow faster than those of younger workers.[5] However, under plausible assumptions about the correlation between wages, experience, and skills, our analysis indicates that higher returns to these factors predominantly expand the age wage gap through a larger distributional gap, a conclusion that clashes with our prior findings.

We also consider changes in the availability of different jobs. The decline in manufacturing (Charles, Hurst, and Schwartz, 2019), a sector in which less experienced workers once commanded relatively higher wages, may have widened the age wage gap by nudging younger workers toward sectors with lower starting wages. However, our results show a rather uniform expansion of the age wage gap across all two-digit sectors, both within and outside manufacturing. Similarly, Deming (2021) shows that the share of decision-intensive occupations, in which more experienced older workers are more productive than less experienced younger workers, has been rising, steepening the wage curve over the life cycle. However, unlike the increased availability of decision-intensive jobs, 88 percent of the age wage gap's expansion between 2012 (first year with occupation data) and 2019 occurred within one-digit ISCO-08 occupation codes, rather than between them. This finding aligns with the conclusion in Acemoglu, Mühlbach, and Scott (2022) that the rise in the "age-friendliness" of jobs did not disproportionately benefit older workers.

In conclusion, this paper offers three main contributions. First, our results contribute to the literature that studies changes in younger workers' labor outcomes. Other papers (Rosolia and Torrini, 2007; Naticchioni, Raitano, and Vittori, 2016; Guvenen et al., 2022; Guaitoli and Pancrazi, 2023) use wages, total income, or lifetime income to show the deterioration of younger workers' careers. We complement their findings by demonstrating the existence of an expanding age wage gap over a long period and across many countries and by testing different theories about the origins of this expansion.

Second, this paper contributes to the literature that studies the interconnectedness of coworkers' career trajectories. Prior work has documented that limited career opportunities can generate negative career spillovers across coworkers in bureaucracies (Bertrand et al., 2020), sports (Brown, 2011; Gong, Sun, and Wei, 2017), firms in transitioning economies (Friebel and Panova, 2008), and privately owned firms in high-income economies (Bertoni and Brunello, 2021; Boeri, Garibaldi, and Moen, 2022; Bianchi et al., 2023; Ferrari, Kabátek, and Morris, 2023; Mohnen, forthcoming). Building upon these insights on negative career

[5] There is mixed evidence on the pattern followed by returns to experience. For example, Jones (2009) shows that they have increased in innovation-centric occupations due to a higher "burden of knowledge." However, beyond these specific jobs, one of the main takeaways in Jeong, Kim, and Manovskii (2015) is that a larger supply of older workers in the labor market decreased the price of experience.

spillovers, our analysis proposes an explanation that reconciles the widening age wage gap with the increased supply of older workers.

Third, this paper explores the connection between the growth of the age wage gap and other wage trends and labor-market dynamics. We consider several explanations alternative to negative career spillovers, such as wage inequality (Piketty and Saez, 2003; Autor, Katz, and Kearney, 2008), changes in the returns to experience (Jones, 2009; Jeong, Kim, and Manovskii, 2015; Azoulay et al., 2020), skill-biased technological change (Autor, Katz, and Kearney, 2006; Acemoglu and Autor, 2011), change in workforce composition, the decline in manufacturing (Autor, Dorn, and Hanson, 2013; Charles, Hurst, and Schwartz, 2019; Acemoglu and Restrepo, 2020), the rise in the age-friendliness of occupations (Deming, 2021; Acemoglu, Mühlbach, and Scott, 2022), and domestic outsourcing (Goldschmidt and Schmieder, 2017; Drenik et al., 2023). Overall, negative career spillovers appear to be a better fit for the characteristics of the widening of the age wage gap.

## 2 The Widening of the Age Pay Gap

### 2.1 Italian Social Security Data

Our empirical analysis uses thirty-five years of confidential administrative data provided by the Italian Social Security Institute (INPS). This dataset comprises matched employer–employee records for the whole population of private-sector, nonagricultural firms with at least one salaried employee. The dataset combines individual-level information about workers, such as age and other demographic characteristics, wage, and contract type, with firm-level information, such as sector, location, and age.

In each year of the data, we restrict our analysis to workers who were at least sixteen years old, had worked at least six months, held a full-time contract, had earned strictly positive wages, and had not retired by December 31. We impose these restrictions to weed out workers with very short-lived job spells within each year.

This dataset allows us to employ two wage measures. First, we utilize the total yearly labor earnings, which include wages and the bonus payments received by many Italian workers.[6] Second, we compute weekly wages by dividing the yearly labor earnings by the number of working weeks. This new variable may conflate variation in hours worked and pay rates but only if workers differ in the number of days they work within a week. Although this is possible, it is important to note that our analysis focuses on full-time employees, who therefore display little variation along this dimension. All measures of labor earnings are ex-

[6] The most common bonus payments are called the "thirteenth" and "fourteenth" salary. The thirteenth salary is a mandatory bonus payment given to employees at the end of December. The fourteenth salary is a voluntary bonus usually paid during the summer.

pressed in 2015 euros, using the conversion tables prepared by the OECD.[7] Moreover, they are winsorized at the 99.9$^{th}$ percentile to limit the influence of extreme outliers.[8]

In total, this dataset includes 312 million observations with information on 28,911,242 full-time workers and 3,532,905 firms between 1985 and 2019 (Table A1, Panel A).

## 2.2 The Age Pay Gap in Italy

The Italian data indicate that the wages of older workers have grown at a much faster rate than those of younger workers for at least the past four decades. The difference between the mean log weekly wages of workers over 55 years old (thereafter, *O55 workers*) and workers under 35 years old (*U35 workers*) grew by 0.19 log points, a 96 percent increase from the level in 1985 (Figure 1, Panel A). This increase is only slightly larger (+0.2 log points) when using yearly labor earnings, rather than weekly wages (Figure C1, Panel A).

This large widening of the age pay gap has not happened only at the average, but rather at every point of the distribution of weekly wages (Figure C1, Panel C). For instance, the age gap increased by 0.2 log points at the 10$^{th}$ percentile, by 0.1 log points at the 25$^{th}$ percentile, by 0.14 log points at the median, by 0.25 log points at the 75$^{th}$ percentile, and by 0.18 log points at the 90$^{th}$ percentile.

This trend has led to a stark steepening in the age profile of wages (Figure 1, Panel B). Between 1985 and 2019, U35 workers experienced at most a 14-percent growth in real weekly wages, while O55 workers experienced wage increases between 33 percent for 56-year-olds and 53 percent for 65-year-olds.

While the age pay gap has widened, the workforce has significantly aged. The mean worker age increased by 19 percent from 35.8 years in 1985 to 42.7 years in 2019 (Table A3, Panel A, columns 1 and 2). Three main post-World-War-II demographic trends can explain this major aging of the workforce. First, the birth rate in Italy decreased from 18.1 births per 1,000 people in 1960 to 7.3 births per 1,000 people in 2018.[9] Second, life expectancy at birth increased by 21 percent from 1960 to 2018, moving from 69.1 years to 83.3 years.[10] These two factors contributed to the increased aging of the population as a whole. Third, a series of pension reforms progressively increased the minimum age of eligibility for receiving public pensions, resulting in older workers spending more time in the labor force before

[7] The tables can be downloaded from https://data.oecd.org/price/inflation-cpi.htm.

[8] We also cap the minimum of yearly earnings at €3,000 in real terms in order to eliminate a few observations with very low pay.

[9] https://web.archive.org/web/20210219221740/https://data.worldbank.org/indicator/SP.DYN.CBRT.IN?end=2018&locations=IT&start=1960

[10] https://web.archive.org/web/20210219221923/https://data.worldbank.org/indicator/SP.DYN.LE00.IN?end=2018&locations=IT&start=1960

retirement.[11]

## 2.3 The Age Pay Gap in Other High-Income Countries

In addition to the Italian data, we have access to confidential employer-employee Social Security data for Germany, as well as labor survey data from the Luxembourg Income Survey (LIS) database for other fourteen high-income countries.[12] These data source confirm that the widening pay gap between older and younger workers, paired with the progressive aging of the workforce, are not exclusive features of the Italian labor market (Table A3).

The labor earnings of O55 workers have grown at a much faster pace than those of U35 workers in all the other fourteen countries in our sample. For instance, the age pay gap increased by 0.14 log points or 61 percent in the United States (1979-2018), by 0.04 log points or 41 percent in the United Kingdom (1979-2018), by 0.17 log points or 46 percent in Canada (1973-2018), and by 0.1 log points or 36 percent in Germany (1996-2017).

Finland and Denmark provide two other interesting case studies. These countries started with very low degrees of disparity between older and younger workers: in 1987, the age wage gap was only 0.04 log points in Finland and 0.16 log points in Denmark. In comparison, the pay gap between O55 workers and U35 workers in 1987 was equal to 0.27 log points in Italy and 0.25 log points in the United States. However, their pay gaps then experienced a steep increase, growing by 0.21 log points in Finland and 0.19 log points in Denmark by the end of 2016.

During the same period, in all but one country in our sample (Israel), the mean age of the workforce has increased.[13] For example, the mean workforce age increased by 12 percent in the United States (1979-2018), by 9 percent in the United Kingdom (1979-2018), by 2 percent in Canada (1973-2018), and by 9 percent in Germany (1996-2017).

In conclusion, the widening of the age pay gap is a pervasive phenomenon that transcends the Italian labor market. It is present in countries with more liberal economic institutions than the Italian ones (such as the United States, the United Kingdom, and Canada), in Northern European countries with extensive welfare states (such as Germany, Denmark, and

[11] In the last three decades, the 1992 "Amato reform," the 2007 "Prodi reform," and the 2011 "Fornero reform" successively raised the minimum thresholds for pension eligibility for most workers in the private sector.

[12] These countries are Australia, Canada, Denmark, Finland, France, Germany, Greece, Israel, Netherlands, Norway, Spain, Switzerland, the United Kingdom, and the United States. Unlike the administrative data provided by the Institute for Employment Research (IAB), the German survey data from LIS originate from the Socio-Economic Panel (SOEP) managed by the German Institute for Economic Research (DIW Berlin).

[13] Compared with other high-income economies, Israel's population, not just its workforce, has been growing at a much faster rate due to natural growth and international immigration (https://web.archive.org/web/20230420170222/https://www.cbs.gov.il/en/mediarelease/pages/2022/population-of-israel-on-the-eve-of-2023.aspx).

Finland), as well as in other Southern European countries (such as Greece and Spain).

Beyond these initial facts, our analysis will show that the various databases lead to similar takeaways about the employment patterns of younger and older workers, at least based on the subset of empirical exercises that can be replicated in multiple countries. Therefore, for the sake of brevity, the rest of the paper will focus on the analysis of the Italian administrative data, the most extensive and detailed data source available to us. However, Appendix A includes more details about the findings obtained using the other secondary datasets.

# 3 A Stylized Framework of Career Spillovers

## 3.1 Negative Career Spillovers

In spite of a substantial rise in the relative supply of older workers, the pay gap between older and younger workers has been expanding in many high-income economies. Career spillovers, as initially defined by Bianchi et al. (2023), are one possible explanation for this trend.

Negative career spillovers imply that an increase in the relative supply of older workers can restrict access to higher-paying positions for younger workers. When the mean worker age grows, for example due to a combination of overall population aging and higher retirement age, there are more older workers who are active in the labor market, accrue more seniority, and can advance further up organizational hierarchies.[14] Consequently, more higher-ranked positions become occupied by older workers, while younger workers become more likely to hold lower-paying jobs and face prolonged wait times for accessing higher-paying roles.

In a frictionless labor market (Baker, Gibbs, and Holmström, 1994), these negative career spillovers cannot exist. In fact, a younger worker who is qualified to obtain a promotion would not be hindered from receiving it by older coworkers occupying higher-ranked jobs for a longer time, as her employer would create a new higher-level position or another firm would poach her. In order to allow for career spillovers, we introduce two frictions to an otherwise standard model of the labor market. We then use this stylized framework to isolate several predictions that we are going to later test on the data.

The first deviation from a frictionless setting is that firms cannot or do not want to fully renegotiate the contracts of older workers, even when their relative supply changes. Various factors can make the wages of incumbent workers stickier, such as backloaded wages (Ke, Li, and Powell, 2018), firm-specific human capital (Lazear, 2009; Gathmann and Schönberg, 2010), knowledge spillovers (Cornelissen, Dustmann, and Schönberg, 2023), and layoff costs (Bentolila and Bertola, 1990). Regardless of the specific mechanism, prior research has documented that workers often receive rents for longer tenure at their firm.

[14] Prior research has highlighted the crucial role of seniority in promotion decisions (Carmichael, 1983; Waldman, 1990; Prendergast and Topel, 1996; Li, Powell, and Ke, 2018).

Next, at least some firms must face constraints in adding higher-level positions. In most high-income economies, the labor markets have been experiencing declines in labor productivity (Byrne, Fernald, and Reinsdorf, 2016; Syverson, 2017), in GDP growth (Antolin-Diaz, Drechsel, and Petrella, 2017), and in firm dynamism (Decker et al., 2014; Foster, Grim, and Haltiwanger, 2016), which can all contribute to firms facing growing difficulties in expanding their ranks, especially at the top. When the relative supply of older workers increase, this friction implies that firms' hierarchies are not sufficiently flexible to create paths toward top jobs for all workers who deserve a promotion.

## 3.2 Setup With a Representative Firm

We start from an economy with a representative firm. The economy is populated by $l_y$ younger workers and $l_o$ older workers, who are homogeneous within each age group.[15]

**Production.** The representative firm employs these two imperfectly substitutable labor inputs to perform two jobs: a top job $t$ and a bottom job $b$. Production occurs through the production function $Y(L_y, L_o)$, with $Y_{L_y} > 0$, $Y_{L_o} > 0$, $Y_{L_y,L_y} \leq 0$, $Y_{L_o,L_o} \leq 0$, and $Y_{L_y,L_o} > 0$. The inputs $L_y$ and $L_o$ are effective units of labor such that $L_a = \theta_{a,t} l_{a,t} + \theta_{a,b} l_{a,b}$ for $a \in \{y, o\}$, where $l_{a,t}$ and $l_{a,b}$ are the number of workers of age group $a$ employed in the top and bottom job, respectively, while $\theta_{a,t}$ and $\theta_{a,b}$ are their productivities. We assume $\theta_{a,t} > \theta_{a,b}$ for any age group $a$ to make all workers more productive in the top job.

**Wage rents.** Wages are set in a competitive labor market. Firms optimally decides how many younger workers to slot in the top job and in the bottom job. so that the marginal revenue products of labor equal their marginal costs. We assume that the top job pays an exogenous rent over the bottom job: $w_{a,t} = \mu_a w_{a,b}$, where $\mu_a > 1$ is the wedge between the top and the bottom job for age group $a$, and $w_{a,b}$ is the wage in the bottom job $b$ for workers in age group $a$. Acemoglu and Restrepo (2023) shows that these rents can be micro-founded by using efficiency wages to limit shirking or by introducing bilateral bargaining to capture the fact that jobs, for example, have different degrees of protection from unions.

**Two frictions.** We introduce two key features to generate career spillovers in this model.

First, we assume that the firm cannot perfectly renegotiate the wages and job allocations of older workers. The firm inherits older workers in each job from the period before the start of the game. These *legacy workers* in job $j \in \{t, b\}$ are equal to $\rho_j l_{o,j}^{-1}$, where $\rho_j$ is the retention rate in job $j$, and $l_{o,j}^{-1}$ is the number of older workers in job $j$ in the pre-game period $-1$. Moreover, we assume that wages of older workers are also inherited from period $-1$ and

[15] This is a simplifying assumption that allows us to study the case in which everyone would deserve a promotion, but higher-ranked positions are rationed. Bianchi et al. (2023) develops a model of career spillovers with heterogeneous workers.

are not renegotiable in period 0. However, the firm can demote $x_o$ older workers from the top to the bottom job by paying a convex cost $c(x_o)$. This assumption captures the idea that wages of incumbent workers are stickier than those of new entrants. This is the case, for instance, if the firm backloads wages to later career stages in order to motivate workers and limit turnover (Ke, Li, and Powell, 2018), or if there is increasing employment protection for older, more tenured workers (Boeri and Jimeno, 2005; Saez, Schoefer, and Seim, 2023). We further assume that the marginal increase in demotions that follow a larger supply of older workers in the top job is lower than the retention rate in the top job: $\partial x_o / \partial l_{o,t}^{-1} < \rho_t$.

Second, we assume that the top job has an administrative cost $\kappa$ per worker. In addition to higher pay, higher-ranked positions usually entail complex tasks, more autonomy to make consequential business decisions, and management responsibilities. So, when the firm thinks about adding a new higher-level position, it has to assess (i) whether there is enough room in the payroll budget for an additional wage, and (ii) whether there is sufficient organizational capacity for this role to receive important tasks and responsibilities. The parameter $\kappa$ captures this additional organizational burden.

In relation to this cost, the firm faces a constraint on the resources that it can spend before production to (i) maintain top jobs and (ii) demote older employees to the bottom job. This constraint is such that $\kappa \cdot (l_{o,t} + l_{y,t}) + c(x_o) \leq K$, where $l_{o,t} = \rho_t l_{o,t}^{-1} - x_o$ is the number of older workers employed in the top job in the current period. The parameter $K$, the maximum amount of resources the firm can spend on higher-ranked positions and demotions, can be written as a function of aggregate economic growth $K\left(\frac{A}{A^{-1}}\right)$, where $A/A^{-1}$ measures the growth rate in GDP or TFP between period 0 and $-1$. This extension captures that fact that macroeconomic trends, such as periods of lower or higher GDP growth, can affect how binding this organizational constraint is for the firm.

**Timing.** The timing of the game is as follows. First, the firm receives the legacy older workers from period $-1$. Then, the firm optimally decides the employment levels of younger workers and the demotion of older workers. Based on these decisions, the firm offers each younger worker a nonnegative wage for the bottom job, $w_{b,y} \geq 0$. The younger workers then decide whether to accept the offer or reject it in favor of an outside option with a zero payoff. If they accept the offer, the firm allocates younger workers randomly between the top and bottom job until they are all employed. Finally, the production is realized, and the firm makes payments to all workers.

**The firm problem.** The firm problem is to choose the number of younger workers in the bottom job, the number of younger workers in the top job, and the number of older workers to demote from the top job in order to maximize its profits,

$$\max_{l_{y,t},l_{y,b},x_o} Y\left(L_y, L_o\right) - \sum_{a=y,o}\sum_{j=t,b} w_{a,j} l_{a,j} - \kappa \cdot \left(l_{o,t} + l_{y,t}\right) - c\left(x_o\right),$$

subject to two constraints. First, the firm faces a constraint on the organizational cost of maintaining top jobs and demoting older workers ($\kappa \cdot \left(l_{o,t} + l_{y,t}\right) + c\left(x_o\right) \leq K$). Second, it needs to satisfy a participation constraint such that workers prefer to work at the firm, instead of choosing their zero-payoff outside option.

## 3.3 Optimal personnel choices.

Within this framework, we first examine how an increase in the supply of older workers affects the wages of younger workers when the organizational constraint on top jobs binds.[16] All proofs are in Appendix B.

**Proposition 1.** *When the organizational constraint on top jobs binds, a larger cohort of legacy older workers in the top job causes the following change in the average wage of younger workers ($\bar{w}_y$):*

$$\frac{\partial \bar{w}_y}{\partial l_{o,t}^{-1}} = \underbrace{\frac{\partial l_{y,t}}{\partial l_{o,t}^{-1}} \frac{1}{l_y} \left(\mu_y - 1\right) w_{y,b}}_{\textit{Crowding out}} + \underbrace{Y_{L_y L_o} \frac{1}{l_y} \theta_{y,b} \rho_t \theta_{o,t} \left(l_{y,b} + \mu_y l_{y,t}\right) - Y_{L_y L_y} \frac{1}{l_y} \rho_t \theta_{y,b} \left(\theta_{y,t} - \theta_{y,b}\right) \left(l_{y,b} + \mu_y l_{y,t}\right)}_{\textit{Relative labor supply}}. \tag{1}$$

An increase in the number of older workers in the top job exerts two opposite forces on the mean wage of younger workers. First, the mean wage of younger workers decreases due to crowding out in the top positions ($\partial l_{y,t}/\partial l_{o,t}^{-1} = -\rho_t + \partial x_o/\partial l_{o,t}^{-1} < 0$), which is the core idea behind negative career spillovers. When the organizational constraint binds, more older workers in the top job induce the firm to assign more younger workers to the bottom job. Second, the mean wage of younger workers increases due to a larger relative supply of older workers. The positive contribution of this channel is twofold. More older workers directly increase the marginal product of younger workers due to their complementarity ($Y_{L_y L_o} > 0$).[17] Moreover, they decrease younger workers' effective units of labor by pushing them toward the bottom job, therefore increasing the marginal revenue product of labor ($Y_{L_y L_y} < 0$). In

[16] Specifically, we are assuming that the firm optimized the worker allocation in period $-1$ without anticipating that more legacy workers and the binding organizational constraint would have limited access to top jobs for younger workers in period 0.

[17] Prior research on demographic shifts in the workforce mostly focused on this mechanism (Welch, 1979; Freeman, 1979).

Appendix B, we show that an increase in the retention rate of legacy older workers ($\rho_t$) and a decrease in the growth rate of the economy ($A/A^{-1}$), two changes that have taken place contemporaneously with an increase in the number of older workers, have similar effects on the mean wage of younger workers.

Crucially, Proposition 1 generates several predictions that can be tested empirically. First, younger workers should face increasing difficulties in reaching higher-paying jobs. Second, the overall effect of an increase in the supply of older workers on the mean wage of younger workers is ex-ante ambiguous. On the one hand, there is a negative effect that stems from the less favorable positions of younger workers in the overall wage distribution and in firms' organizational hierarchies. On the other hand, younger workers' wages in different jobs increase. Therefore, if negative career spillovers are important, we should observe that the age pay gap has been widening primarily because the position of older and younger workers in the wage distribution has been diverging. Third, although Proposition 1 is fully static, it is possible to infer its dynamic repercussions on the career progression of younger workers. Specifically, a decline in younger workers' probability of holding top jobs should stem from both (i) a lower probability of joining the labor market in higher-ranked positions, and (ii) a lower probability of being promoted to higher-ranked positions during early-career stages.

**Proposition 2.** *The number of younger workers in the top job decreases as the organizational constraint becomes more binding:* $\frac{\partial l_{y,t}}{\partial K} < 0$.

Proposition 2 indicates that the career spillovers on younger workers should be more negative within firms that face tighter constraints in adding higher-ranked positions to their hierarchies. As shown by Bianchi et al. (2023), these firms tend to be in a more mature stage of their life cycle: they are usually older and larger, and their workforce grows more slowly.

Furthermore, Proposition 1 and Proposition 2 help explain why the age pay gap widened both when the large baby-boom cohorts entered the labor market in the late 1960s (Welch, 1979; Freeman, 1979), and when they reached later career stages (Section 2). All demographic shocks have more negative effects on the employment opportunities of younger workers, because older workers' wages are stickier. In the 1960s, a sharp increase in the supply of younger workers expanded the age pay gap by decreasing younger worker's marginal revenue product of labor and possibly by increasing the probability of younger workers holding bottom jobs (if the organizational constraint was already binding). By the mid 1980s, the baby-boomers had accrued enough seniority to occupy many high-ranked positions, so that the age pay gap kept widening because new entrants started experiencing a slower career growth.

## 3.4 Setup With Heterogeneous Firms

We now modify the previous framework to introduce heterogeneous firms. This extension allows us to study how an increase in the supply of older workers affect the distribution of younger workers across higher-paying and lower-paying firms.

**Heterogeneous firms.** Following Card et al. (2018) and Lamadon, Mogstad, and Setzler (2022), we model a labor market with asymmetric information where firms are heterogeneous in both productivity and amenities, and workers have firm-specific preferences.

On the labor-supply side, we assume that worker $i$ of age group $a \in \{y, o\}$ derives the following utility when working in job $j \in \{t, b\}$ and firm $f \in \{1, \ldots, F\}$:

$$U_{i,a,j,f} = \log(w_{a,j,f}) + \log(X_{a,j,f}) + \xi_{i,a,j,f},$$

where $X_{a,j,f}$ is the value that workers in age group $a$ attribute to the amenities in job $j$ of firm $f$, and $\xi_{i,a,j,f}$ is worker $i$'s idiosyncratic taste shock for firm $f$ and job $j$. We assume that $\xi_{i,a,j,f}$ follows a type-1 extreme distribution with parameter $\sigma > 0$, and cannot be observed by firms. The parameter $\sigma$ captures the degree of substitutability across firms and jobs in workers' preferences.

On the labor-demand side, firms are heterogeneous in their productivity $A_f$. In line with Card et al. (2018) and Lamadon, Mogstad, and Setzler (2022), we assume that, when firms choose what wages to post for their top and bottom jobs, they fully anticipate the consequences of these choices on their own labor supply, but disregard any effects on the economy-wide level of wages.[18] In this extension, we drop the assumption that wages in the top jobs always pay a constant rent over wages paid in the bottom job. Relaxing this assumption implies that an increase in the number of older workers does not necessarily lead to larger changes in both bottom and top wages in the same set of firms. Moreover, to simplify the analysis on younger workers' employment, we assume that firms cannot demote older workers in period 0. Therefore, at the beginning of the game, firm $f$ inherits $\rho_{j,f} l_{o,j,f}^{-1}$ legacy older workers in job $j$ whose contracts are fully non-renegotiable. We further assume that $\rho_{j,f}$ increases with firm-level productivity $A_f$, indicating that worker retention is higher among higher-paying firms.[19] Appendix B outlines the firm problem and derives the optimal level of wages in both jobs for each firm.

[18] Another way to formulate this assumption is that the number of firms $F$ is very large, so that each individual firm does not internalize the consequences of its actions on the other players in the market.

[19] This assumption, which can be micro-founded by directly modeling older workers' retirement choice, is consistent with prior work (for example, Bender et al. (2018) and Ruffini (2022)) that has documented a strong correlation between worker retention, firm productivity, and compensation levels.

**Proposition 3.** *When the organizational constraint in firm $f$ is binding, an increase in the total number of older workers in the labor market has the following effects on younger workers' employment:*

*a)* $\frac{\partial l_{y,t,f}}{\partial l_o} < 0$*;*

*b)* $\frac{\partial^2 l_{y,t,f}}{\partial l_o \partial A_f} < 0$*;*

*c)* $\frac{\partial^2 l_{y,b,f}}{\partial l_o \partial A_f} < 0$ *if* $\frac{\frac{\partial w_{y,b,f}}{\partial l_o}}{w_{y,b,f}} > \frac{\frac{\partial w_{y,b,f'}}{\partial l_o}}{w_{y,b,f'}}$ *for any pair of firms $f$ and $f'$ such that $A_f < A_{f'}$.*

Proposition 3 provides three predictions about cross-firm differences in negative career spillovers. First, an increase in the supply of older workers should decrease younger workers' employment in the top jobs for each firm in which the organizational constraint is binding. Therefore, if limitations to the creation of new higher-ranked positions are widespread in the economy, we should expect to observe negative career spillovers across firms with varying productivity and wage levels.

Second, these negative career spillovers should be larger in magnitude among higher-productivity firms. This conclusion follows from the distribution of older workers' retention rates. Since retention rates are higher among higher-productivity firms (where wages are also higher), an increase in the overall number of older workers leads to more congested access to the top jobs of these same firms, causing a more pronounced slowdown in the careers of their younger employees.

Third, younger workers are more likely to move to firms in which bottom-job wages display higher percentage increases. A larger supply of older workers increases younger workers' wages in the bottom jobs due to the relative-labor-supply channel already discussed in Section 3.3. Proposition 3 illustrates that, while the employment of younger workers in *top jobs* declines the most in higher-productivity firms, younger worker's employment in *bottom jobs* does not necessarily increase the most in the same set of firms. In fact, the firms that experience the highest percentage increase in bottom-job wages could be the least productive ones, primarily because their wage levels are lower at baseline. In short, more congestion in top jobs within higher-productivity and higher-paying firms can theoretically affect the distribution of workers between firms, generating a migration of younger workers toward the bottom jobs of lower-productivity and lower-paying firms. This hypothesis will find support in the data.

## 3.5 Summary

Our stylized framework highlights how an increase in the supply of older workers can lead to negative career spillovers for younger workers. It does so by introducing two additions to an otherwise standard model of the labor market: labor contracts of incumbent workers are not

fully renegotiable, and at least some firms face constraints in creating higher-ranked positions. This framework generates several empirically testable insights about the employment opportunities of younger workers. When older workers become more numerous at the top of the wage distribution:

1. Younger workers face increasing difficulties in reaching the top of the wage distribution, while the overall effect on their mean wage is ex-ante ambiguous.

2. The age pay gap widens primarily due to younger workers' positional losses and older workers' positional gains in the wage distribution.

3. Younger workers join the labor market lower in the wage distribution and experience slower growth in the years after entry.

4. Younger workers' positional losses in the wage distribution are more negative within firms that face more challenges in adding higher-ranked positions.

5. Younger workers face positional losses in both higher-paying and lower-paying firms, but these losses are more negative in higher-paying firms.

6. More congestion within higher-paying firms can push younger workers toward lower-paying firms.

Each of these insights receives empirical support. We also discuss alternative interpretations of our empirical results in Section 5.

# 4 Evidence of Career Spillovers

## 4.1 The Slower Career Progression of Younger Workers

One of the core implications of our framework, declined over its first three empirical predictions, states that negative career spillovers contribute to widening the age pay gap by slowing down the career progression of younger workers. Section 4.1.1 shows that younger workers have become progressively less likely to hold higher-paying positions. Section 4.1.2 proposes a formal decomposition of the trend in the age pay gap to quantify the contribution of negative career spillovers. Finally, Section 4.1.3 shows that younger workers fared progressively worse both at and after labor-market entry.

### 4.1.1 The Position of Younger Workers in the Wage Distribution

Consistent with Prediction 1, younger workers have become less likely to reach the top of the wage distribution, where older workers have become significantly more represented.

The probability of U35 workers belonging to the top quartile of the distribution of weekly wages decreased by 34 percent, from 15 percentage points in 1985 to 10 percentage points in 2019 (Figure 2, Panel A). This decline at the top of the distribution coincided with an increased probability of U35 workers being in the lowest quartile (+23 percent). In contrast, O55 workers experienced the opposite trend (Figure 2, Panel B). Their probability of being in the top quartile rose from 32 percentage points in 1985 to 37 percentage points in 2019, while their probability of being in the bottom quartile declined from 23 percentage points in 1985 to 18 percentage points in 2019.

This finding becomes even more pronounced when examining vigintiles (Figure 2, Panel C). In stark contrast with the trend experienced by O55 workers, the share of U35 workers decreased nearly monotonically from the lowest to the penultimate vigintile between 1985 and 2019.

In addition to analyzing shifts along the wage distribution, we can look more closely at career trajectories within firms' hierarchies. Starting from 1996, the dataset has information on the four official hierarchical levels in the Italian labor system: apprentices, blue-collar workers, white-collar workers, and managers.[20] The percentage of managerial jobs held by U35 workers decreased from 8 percent in 1996 to 3 percent in 2019, while the share held by O55 workers more than doubled during the same period (Figure 2, Panel D).

#### 4.1.2 The Change in Pay Rank

Using an empirical test similar to the one in Bayer and Charles (2018), we measure how much opposite movements of younger and older workers along the wage distribution have contributed to widening the age pay gap. Consistent with Prediction 2, the results indicate that the age pay gap has been increasing predominantly due to younger workers' positional losses and older workers' positional gains in the wage distribution.

The change in the mean log wage of workers in age group $a$ between years $t$ and $t'$ can be written as follows:

$$\Delta w_a^{t,t'} = \underbrace{\sum_v \left(s_{a,v,t'} - s_{a,v,t}\right) \bar{w}_{v,t}}_{\text{Pay rank change}} + \underbrace{\sum_v s_{a,v,t} \left(\bar{w}_{v,t'} - \bar{w}_{v,t}\right)}_{\text{Distributional change}} + \underbrace{\varepsilon_a^{t,t'}}_{\text{Residual}} . \tag{2}$$

In this equation, $s_{a,v,t}$ is the share of workers in age group $a \in \{\text{U35}, \text{O55}\}$, in vigintile $v$ of the distribution of wages, and in year $t$, while $\bar{w}_{v,t}$ is the mean log wage in vigintile $v$ and year $t$. Appendix C.2 describes all the steps required to obtain this decomposition.

[20] In addition to actual managers ("*dirigenti*"), the last category includes the so-called "*quadri*," who are high-ranked workers with important responsibilities and significant autonomy.

When $a$ = U35, Equation (2) indicates that a change over time in the mean wage of younger workers comprises three components. First, the mean wage of younger workers can change due to variation over time in the share of younger workers in each vigintile of the wage distribution, while keeping the mean log wages in each vigintile fixed in the baseline year. This first component, a change in the *pay rank,* is related to the crowding-out portion of Equation (1): it isolate wage changes that arise exclusively from shifts along the wage distribution, while the overall shape of the wage distribution remains unchanged. Second, the mean wage of younger workers can change due to variation over time in the wages earned in different vigintiles of the distribution, while keeping the share of younger workers in each vigintile fixed at baseline. This second component, a *distributional change*, is related to the relative-labor-supply portion of Equation (1): it measures how much a change in the support of the wage distribution affect the mean wage of younger workers, while preventing them from moving along the wage distribution. Finally, the third component is a *residual* resulting from the interaction between pay rank and distributional changes.

We first decompose the change in mean log weekly wages between 1985 and 2019 separately for U35 and O55 workers (Figure 3, Panel A). In line with Prediction 1, we find that the overall change in the mean wage of younger workers is the product of two opposite forces. On the one had, the change in the pay rank is negative: abstracting from any change in the level of real wages paid in the economy, the movement of younger workers toward the bottom of the wage distribution decreased their mean wage by 0.09 log points. On the other hand, the distributional change is positive: keeping younger workers in the same positions they held in 1985, changes in the wages paid in different parts of the pay distribution increased the mean wage of U35 workers by 0.24 log points.

In order to understand the contribution of these two channels to the widening of the age pay gap, we need to look at the same decomposition for O55 workers. Relative to U35 workers, older workers experienced an increase in pay rank (+0.06 log points) and a slightly larger distributional change (+0.27 log points). These conclusions hold if we decompose the change in mean wages for individual age bins (Figure 3, Panel B), suggesting that the classification we use for younger (U35) and older (O55) workers does not qualitatively affect the main findings.

Consistent with Prediction 2, we conclude that the age pay gap has been widening mainly due to opposite movements of younger and older workers along the wage distribution. To better visualize this result, we apply the decomposition in Equation (2) to the age pay gap (see Appendix C.2 for the full derivation). By 2019, the gap in pay rank accounted for 78 percent of the total increase in the age wage gap between U35 workers and O55 workers (Figure 3, Panel C). Moreover, the pay rank gap was the primary driver of the widening in

the age gap throughout the period under consideration, contributing between a minimum of 53 percent in 1987 and a maximum of 81 percent in 2004. These findings hold when we substitute yearly earnings for weekly wages (Figure C2).

#### 4.1.3 Entry Pay Rank and Pay Rank Growth

In this section, we test Prediction 3, which states that, when the concentration of older workers in higher-paying positions increases, younger workers both (i) enter the labor market at lower sections of the wage distribution, and (ii) experience slower growth along the wage distribution after labor-market entry.

To study entry and post-entry conditions, we decompose the change in pay rank of U35 workers between year $t$ and $t'$ as follows:

$$\underbrace{\sum_{v}\left(s_{U35,v,t'}-s_{U35,v,t}\right)\bar{w}_{v,t}}_{\text{Pay rank change}} \approx \underbrace{\sum_{e\in[0,18]} s_{e,t}\cdot\sum_{v}\left[\left(s^{LME}_{e,t',v}-s^{LME}_{e,t,v}\right)\cdot\bar{w}_{v,t}\right]}_{\text{Change in entry pay rank}} + \underbrace{\sum_{e\in[0,18]} s_{e,t}\cdot\sum_{v}\left[\left(\Delta s^{t'-LME}_{e,t',v}-\Delta s^{t-LME}_{e,t,v}\right)\cdot\bar{w}_{v,t}\right]}_{\text{Change in pay rank growth}}, \tag{3}$$

where $e \in [0, 18]$ measures years of experience of U35 workers, $s_{e,t}$ is the share of U35 workers with $e$ years of work experience in year $t$, $s^{LME}_{e,t,v}$ is the share of U35 workers with $e$ years of work experience in year $t$ in vigintile $v$ *at the time of labor-market entry* ($LME$), and $\Delta s^{t-LME}_{e,t,v} = s_{e,t,v} - s^{LME}_{e,t,v}$ is the change in the share of U35 workers with $e$ years of work experience in year $t$ in vigintile $v$ between $LME$ and year $t$. Appendix C.3 describes all the steps required to derive this formula.[21]

Equation (3) indicates that the change in younger workers' pay rank comprises two components. The first relates to the difference in the pay rank *at labor-market entry* of U35 workers between time $t$ and $t'$. The second component assesses how the growth in the pay rank of U35 workers *after labor-market entry* changed between $t$ and $t'$. In a plot of pay rank over the life cycle, the first term isolates changes in the intercept of the curve, while the second term depicts changes in the slope for up to eighteen years after labor-market entry.

Consistent with Prediction 3, both entry rank and rank growth have contributed to decrease the pay rank of younger workers (Figure 4, Panel A). By 2019, a progressively lower

[21] Equation (3) is not an exact decomposition of the change in pay rank of younger workers because it keeps the share of U35 workers with $e$ years of work experience fixed at time $t$ ($s_{e,t}$). Robustness checks indicate that the results hold under different assumptions. Moreover, to reduce noise, $LME$ in the data is defined as the first three years of work, rather than just the first one.

rank at entry represented 86 percent of the overall decline in the pay rank of U35 workers, while slower growth in the pay rank in the eighteen years after entry accounted for the remaining 14 percent.

This result is robust to alternative specifications. First, the main finding holds if we replace $s_{e,t}$ in Equation (3) with $s_{e,,t'}$, the share of U35 workers with experience $e$ in the last year of the sample. Fixing the distribution of work experience in a given year allows us to isolate changes in the movements of younger workers along the wage distribution from changes in their mean tenure. This robustness check shows that the choice of the reference year for the distribution of job experience does not seem consequential. Second, the result is quantitatively similar if we decompose the change in the pay rank of U30 workers, rather than U35 workers, over a longer time period (Figure 4, Panel B). The main analysis starts in 1995, one of the first years with information on the entry wage for many U35 workers. Focusing on U30 workers, who on average have shorter careers, allows us to extend back the sample to 1990 without modifying our conclusions.

## 4.2 Evidence of Difficulties In Adding Higher-Ranked Positions

In this section, we show that Prediction 4, which indicates that the negative career spillovers are larger among firms with a more binding organizational constraint, receives empirical support.

Building upon Bianchi et al. (2023), we first categorize firms based on their rate of employment growth (below and above median), their age (at most or above ten years old), and their size (thresholds at 50, 100, and 500 employees). Then, we compute changes in the pay rank and the age pay gap separately across these firm groups. If the data align with the existence of negative career spillovers, we expect to observe that the age pay gap would increase more in larger and older firms in a mature stage of their life cycle, when organizational hierarchies become less flexible.

Consistent with Prediction 4, U35 workers experienced a substantial decline in the rank in the distribution of log weekly wages within all types of firms (Figure 5, Panel A). While the change in the pay rank is negative everywhere, the magnitude of the decline tends to be larger among firms that are more likely to face constraints in adding higher-rank positions to their hierarchies. Specifically, U35 workers faced larger drops in the pay rank in larger firms with below-median growth in their workforce. The data also indicate that the decline in the pay rank is larger within younger firms, but the difference between younger and older firms is small.

These initial findings on the pay rank change of younger workers imply that the age pay gap itself increased more in firms that are more likely to have a binding organization

constraint (Figure 5, Panel B). For example, the age gap in weekly wages increased by 0.24 log points within firms with below-median employment growth, while it increased by only 0.17 log points within firms with above-median employment growth. This difference is both economically and statistically significant: it is equal to 38 percent of the total increase in the age wage gap and is significant at the 1-percent level. Moreover, the age pay gap increased significantly more in firms that employed more workers and, unlike the pay rank of younger workers, in firms that were more than ten years old.

The data also indicate why negative career spillovers may have become more prevalent over time. Between 1985 and 2019, the labor market experienced an increase in the supply of older firms, as well as an overall decline in economic growth (Figure C3). Therefore, in addition to the bottlenecks in firms' hierarchies associated with workforce aging, there are now many more organizations that are less likely to freely add higher-ranked jobs . In fact, even in the absence of workforce aging, firm aging and lower economic growth alone could have generated the observed patterns in the age pay gap (in the framework, decline in $K$).

## 4.3 The Distribution of Workers Within and Between Firms

This section studies how negative career spillovers affect the allocation of younger and older workers across different types of firms. Consistent with Prediction 5, we find that the decline in the mean position of younger workers in the pay distribution of their employers has been larger in magnitude within higher-paying firms, where the supply of older workers has increased the most. Moreover, consistent with Prediction 6, younger workers have become more likely to work for lower-paying firms, while their employment rate has decreased among higher-paying firms, a pattern that contributed to further widening the age pay gap.

Following a process introduced by Machado and Mata (2005), we sort workers into 100 percentiles or *firm groups*, using their firm's average log weekly wage, separately for each year in the sample.[22] Next, for each year, we compute the mean percentile of U35 workers in the firm-group-specific distribution of log weekly wages. Finally, we measure the mean change in the percentile of U35 workers between 1985 and 2019 separately for each firm group. This process allows us to evaluate differences in the movement of younger workers along the wage distribution of lower-paying and higher-paying firms.

The data indicate that the mean percentile of U35 workers decreased in ninety-nine out one hundred firm groups between 1985 and 2019 (Figure 6, Panel A). Moreover, as outlined

[22] In theory, firm groups could coincide with firms themselves. However, in practice, many firms are not large enough to generate meaningful within-firm wage distributions. In most cases, this procedure still ensures that all coworkers are assigned to the same firm group. As a validity check, we compare the worker shares in different vigintiles of the distribution of weekly wages predicted by the sorting procedure to the actual shares observed in the raw data. As expected, the predicted and actual shares are nearly identical (Figure C4).

by the stylized framework, these positional losses were larger in magnitude among higher-paying firms. On average, U35 workers lost 9 percentiles in the top decile of firm groups and only 5 percentiles in the bottom decile.

Next, for each year, we compute the share of younger workers in each firm group out of the total number of younger workers in the market. We repeat the same calculations for older workers. These variables allow us to establish two additional results. First, consistent with Prediction 5, we find that older workers have become more likely to be employed in higher-paying firm groups (Figure 6, Panel B). From 1985 to 2019, O55 workers' share increased on average by 0.3 percentage points in the top decile of firm groups, and decreased by 0.2 percent in the bottom decile. These findings confirm that the increased supply of older workers, and therefore the crowding out of higher-ranked positions, was more severe among higher-paying firms.

Second, consistent with Prediction 6, younger workers have become more likely to find employment in lower-paying firm groups (Figure 6, Panel C). On average, the share of U35 workers decreased by 0.02 percentage points in the top decile of firm groups, and increased by 0.03 percentage points in the bottom decile.

In short, these results confirm that the age pay gap has widened both within and between firms. On the one hand, younger workers have lost positions in the internal wage distribution of firms, especially within higher-paying ones. On the other hand, they have disproportionately moved toward lower-paying institutions.

## 5 Alternative Explanations

This section examines alternative mechanisms, distinct to negative career spillovers, that could explain why the wage growth of older workers has outpaced that of their younger counterparts. Our analysis indicates that while these factors do indeed represent important labor-market dynamics, they do not fully align with the observed trends in the age wage gap.

### 5.1 Wage Inequality

The economic literature has documented a substantial rise in wage inequality in high-income economies (see, for example, Piketty and Saez (2003), Autor, Katz, and Kearney (2008), and Song et al. (2019)). Historically, O55 workers have been more likely to occupy higher-paying jobs, which have been subject to higher increases in mean wages, whereas U35 workers have been often in lower-paying roles, which have experienced smaller or no increases in mean wages. Therefore, higher inequality could have expanded the age wage gap by extending the support of the wage distribution.

Wage inequality, a multifaceted phenomenon with various labor-market and societal repercussions, has a core component that is directly addressed in Equation (??). The distributional gap within this equation isolates the effect of changes in the wage distribution's support on the overall age wage gap, including those changes associated with higher wage inequality. Specifically, it quantifies the impact of variations in mean wages across different vigintiles of the wage distribution (for example, rapid growth at the top and slow growth at the bottom), while the distribution of younger and older workers across vigintiles is held constant at baseline.

However, as discussed earlier, the distributional gap, and therefore one of the core features of wage inequality, can account for only a minor portion of the age wage gap's expansion in most high-income countries (Table A3, column 8).

## 5.2 Higher Returns to Experience and Higher-Level Skills

In this section, we examine whether trends in the returns to experience and higher-level skills may have contributed to widening the age wage gap.

The evidence on the recent trajectory followed by returns to work experience is mixed. On the one hand, prior research has documented that specific occupations became more rewarding for experienced workers. For example, Jones (2009) shows that many academic and scientific tasks have grown more complex, necessitating more advanced skills. This increased "burden of knowledge" has prompted many inventors to extend their investment in education, thereby delaying the peak of their labor earnings. Azoulay et al. (2020) presents similar findings for entrepreneurs. On the other hand, outside of this set of innovation-centric jobs, Jeong, Kim, and Manovskii (2015) shows that an increased supply of older workers led to a decrease in the price of experience, a trend that would have narrowed the age wage gap.

There is stronger agreement in the literature on the fact that returns to higher-level skills have increased in recent decades. Within the rich literature on skill-biased technological change (or SBTC; for an overview, see Acemoglu and Autor (2011)), Autor, Katz, and Kearney (2006) proposes a model in which new technology complements the non-routine tasks integral to high-wage jobs, thus increasing these tasks' value. Older workers, who are more likely than their younger coworkers to engage in these non-routine tasks and whose experience allows them to occupy higher-paying positions, were particularly well positioned to benefit from recent technological advancements. Beyond the evidence on SBTC, prior papers have documented shifts in the labor market's demand for higher-level skills. For example, Deming (2021) shows that the demand for decision-making skills, which improve with experience and tenure, has risen, leading to higher market returns for these skills and increased wages for more experienced workers.

While higher returns to experience and to higher-level skills have the potential to push the wages of younger and older workers further apart, they should do so mainly through a larger distributional gap, a channel that Section 4.1.1 identified as a minor source of the widening in the age wage gap. To clarify this point, consider a simple wage function: $w_{i,a}^t = \beta_0 + \beta_1^t x_{i,a}^t + \varepsilon_i^t$. Here, $w_{i,a}^t$ denotes the wage of worker $i$ in age group $a \in \{\text{Younger}, \text{Older}\}$ in period $t$; the variable $x_{i,a}^t$ represents the quantity of wage-enhancing factor $x$ possessed by worker $i$ in period $t$; the coefficient $\beta_1^t$ is the unit price of factor $x$ in period $t$; and $\varepsilon_i^t$ refers to other characteristics correlated with wages.

The variable $x$ represents any worker characteristic associated with higher wages, such as experience, skills, education, job level, and other features of the labor contracts. Though simple, this equation becomes a standard Mincerian earning function if $x$ is replaced with schooling and a quadratic polynomial of labor-market experience. It also relates to the popular AKM model (Abowd, Kramarz, and Margolis, 1999) since $x$ could include both firm-specific and worker-specific fixed effects. A crucial feature of this wage equation is the unequal distribution of the variable $x$ between younger and older workers. We assume that older workers possess, on average, a higher value for $x$, resulting in a higher mean wage for older workers at baseline—a fact corroborated by all of our available data sources. In contrast, variable $\varepsilon_i^t$ is equally distributed across both worker categories.[23]

To simulate an increase in returns to experience or higher-level skills, we raise the price of the wage-enhancing factor $x$. Given that older workers possess, on average, a larger value for $x$, its price hike amplifies the age wage gap. We then utilize Equation (**??**) to decompose this increase into a larger rank gap and a larger distributional gap.

Without $\varepsilon_i^t$, $x$ is the sole determinant of individual wages. When its unit price $\beta_1$ increases, the resulting expansion of the age wage gap stems entirely from a larger distributional gap between older and younger workers. (Figure C5, Panel A). With $\varepsilon_i^t$, differences in $x$ account for a smaller share of the wage variation (Figure C5, Panel B). Following an increase in the price of $x$, the age wage gap increases, but the contribution coming from the distributional gap declines as the standard deviation of $\varepsilon_i^t$ grows. When the standard deviation of $\varepsilon_i^t$ is sufficiently large, the rank gap accounts for most of the age wage gap's widening.

This simple exercise provides two key insights for understanding the role of higher returns to experience and higher-level skills.[24] First, in the absence of other factors ($\varepsilon_i^t$), a higher price for $x$ increases the age wage gap mainly by moving the two tails of the wage distribution

[23] We calibrate the wage equation to match five key moments from the first sample year of the Italian administrative data. Appendix C.4 includes more details.

[24] Although it does not include an explicit numerical framework, Bayer and Charles (2018) performs a similar analysis (and reaches analogous conclusions) to assess the role of rising returns of education on the racial wage gap in the United States.

further apart (creating a larger distributional gap). For example, given that older workers are on average more experienced than younger workers, a higher price for experience widens the age wage gap by extending the preexisting wage advantage of older workers, rather than allowing older workers to overcome younger workers in the wage distribution. Second, in the presence of other factors, the main channel through which a higher price for $x$ widens the age wage gap depends on the relationship between $x$ and wages. When the $R^2$ between $x$ and wages is larger, the wage distributions of younger and older workers overlap less, and the same conclusions discussed for the case without $\varepsilon_i^t$ apply. Conversely, when the $R^2$ between $x$ and wages is smaller, the wage distributions of younger and older workers overlap more. In this case, a higher price for $x$ is more likely to propel older workers past younger ones in the aggregate wage distribution, thereby expanding the rank gap.

In conclusion, whether higher returns to experience and skills align with the observation that the widening of the age wage gap primarily arises from a larger rank gap depends on the correlation between these variables and wages at baseline. Using Italian administrative data from 1985, we regress log weekly wages on a quadratic polynomial of labor-market experience and on dummies for the four main job levels in the Italian labor market as a proxy for skills. Both the R-squared and adjusted R-squared equal 0.31 when all full-time workers with open-ended contracts are included and drop to 0.26 when the sample is narrowed to only U35 and O55 workers. Given this degree of correlation, our numerical exercise indicates that higher prices for experience and higher-level skills would primarily widen the distributional gap, a conclusion at odds with the nature of age gap's growth discussed in Section 4.1 (Table A3, columns 7 and 8).

## 5.3 Changes in the Characteristics of Younger and Older Workers

This section explores whether changes in the characteristics of younger and older workers have contributed to the age wage gap's expansion. We focus on factors such as the share of temporary or foreign-born workers that are typically associated with below-average wages and which may have risen more rapidly among U35 workers. Our analysis, however, reveals that older workers' wages have outpaced those of younger workers even after controlling for these socio-economic factors.

Whenever these variables are available in the administrative and survey data under our control, we regress log wages on (i) gender (a male dummy); (ii) nationality (a dummy for nonimmigrant workers), except for the United States where the absence of nationality data induces us to use race instead (a dummy for white workers); (iii) contract length (a dummy for temporary contracts), (iv) education (a dummy for college education), and (v) health (a dummy for disability status). We estimate distinct regressions in each year and country,

allowing coefficient estimates to vary over time and geography. We then use the residuals from these regressions to compute the age wage gap.

Controlling for these characteristics does not substantially reduce the growth in the age wage gap (Table C1, columns 1 to 14). For example, the Italian administrative data allow us to control for gender, nationality, and contract length. The residual wages indicate that the age wage gap rose by 0.16 log points, only 13.5 percent less than the unconditional gap increase. This pattern remains broadly consistent across other countries in our sample. Out of 63 measurements with controls, only three cases manifest an increase in the age wage gap that is less than half of the gap expansion without controls.

We now focus on the selection of older workers. The gradual increase in the retirement age may have altered the characteristics of older individuals remaining in the labor markets. Previous studies indicate that this form of selection could be negatively correlated with older workers' earning potential, therefore narrowing the age wage gap (Munnell, Sanzenbacher, and Rutledge, 2018; Kolsrud et al., forthcoming). We provide further evidence that changing selection into retirement is not a primary driver of the growth in the age wage gap by limiting our O55 workers' group to male employees aged between 56 and 60. The rationale for this test is that the minimum retirement age for men was already at least 60 years at the start of our sample in all but two countries in our sample (Table C2). By focusing on this narrower group of older workers, whose selection into retirement is less likely to have changed in recent decades, we find that the widening of the age wage gap remains largely unaltered (Table C1, column 15).

## 5.4 Sectoral and Occupational Shifts

This section evaluates whether changes in job availability have played a central role in expanding the age wage gap. The overall evidence does not fully support this conclusion.

We first investigate secular sectoral shifts away from manufacturing. Prior studies have documented that the decline in manufacturing jobs that started during the early 2000s has contributed to higher unemployment among younger workers with lower skills (Autor, Dorn, and Hanson, 2013; Charles, Hurst, and Schwartz, 2019; Acemoglu and Restrepo, 2020). Therefore, the disappearance of jobs in which younger workers could earn relatively higher wages may be related to the widening age wage gap.

If this hypothesis aligns with the data, the age wage gap should predominantly expand across sectors, as a result of younger workers' outflow from manufacturing. To test this prediction, we modify Equation (**??**) to decompose the change in rank gap between and within sectors. This procedure differs slightly from the decomposition between and within firms in two ways. First, instead of forming 100 firm groups, we create 270 *sector groups*,

one for each three-digit sector in the statistical classification of economic activities of the European Community (NACE Rev. 2). Second, we form 200 worker groups within each three-digit sector, yielding a total of 54,000 *sector-worker groups*.[25] The results indicate that only 2 percent of the rank gap's increase occurred between three-digit sectors (Figure C6, Panel A).

Moreover, we should observe a larger increase in the age wage gap in non-manufacturing sectors in which either the share of younger workers or their mean wage was lower at baseline. These sectors should have received lower-skilled younger workers who had become unable to find employment in manufacturing and were therefore willing to accept lower wages elsewhere. Despite this expectation, the correlation between the widening of the age wage gap and these two baseline characteristics at the two-digit sector level is both statistically and economically insignificant (Figure C6, Panels B and C). For example, a one-standard-deviation (+1.4 percent) increase in the sectoral share of U35 workers in 1985 is associated with 0.0004-log-point lower growth in the rank gap from 1985 to 2019, an effect size equal to just 0.2 percent of the standard deviation of the rank gap's increase. More generally, the expansion of the age wage gap is relatively homogeneous across all sectors, both within and outside manufacturing.

Next, we examine trends in the availability of jobs offering higher returns to experience. As previously discussed, Deming (2021) shows that employment in decision-intensive occupations, in which older workers have an advantage due to their accrued experience, has been on the rise since the 1970s. Therefore, the growing supply of these occupations may have improved older workers' employment opportunities, thereby widening the age wage gap.[26]

This hypothesis implies that the age wage gap has mainly widened across occupations due to older workers transitioning into positions with higher rewards for experience. To test this prediction, we modify Equation (**??**) to decompose the increase in rank gap between and within occupations. We create 10 *occupation groups*, corresponding to each one-digit occupation in the International Standard Classification of Occupations (ISCO-08).[27] Within each group, we subdivide workers into vigintiles, resulting in 200 *occupation-worker groups*. From 2012, the first year with occupation data, nearly all the rank gap's growth occurred within one-digit occupations (Figure C6, Panel D), contributing 81 percent of the total growth by 2015 and 88 percent by 2019.

Moreover, our prior findings on the post-entry wage rank growth of U35 workers allow

[25] We limit worker groups to 200 per sector to ensure sufficient observations in each worker-sector group.

[26] This phenomenon is related to, but different from, an increase in the returns to higher-level skills and experience (discussed in Section 5.2).

[27] One of these one-digit occupations isolates managerial jobs, which by definition are intensely focused on decision making.

us to examine a second prediction. Specifically, a larger supply of occupations with higher returns to experience should be associated with lower initial wages for labor-market entrants, but faster wage growth after entry. In other words, the increasing scarcity of jobs for inexperienced workers should worsen entry conditions, but the wage curve should steepen after entry due to more occupations offering higher rewards for experience. However, these trends, highlighted by Deming (2021) for wage *levels* over the life cycle, do not apply to the variation in wage *rank* across cohorts of younger workers, which is the primary driver of the expanding age wage gap. In line with the existence of negative career spillovers, we have found that both the entry wage rank and the growth in the post-entry wage rank for U35 workers have declined over time, indicating a slowdown in younger workers' career progression for several years after entry (Figure 4). Thus, our analysis supports one of the main conclusions of Acemoglu, Mühlbach, and Scott (2022), which states that the rise in the age-friendliness of jobs has not disproportionately favored older workers.

Finally, we investigate the impact of domestic outsourcing. As demonstrated by Goldschmidt and Schmieder (2017), an increasing number of large firms have started outsourcing low-skill jobs to lower-paying business-service firms. Given that younger workers are more likely to occupy these progressively outsourced low-skill jobs (Figure C7, Panel A), domestic outsourcing could contribute to the widening age wage gap.

If domestic outsourcing were a primary factor, the rank gap should have increased predominantly between sectors.[28] However, we have already established that only 2 percent of the rank gap's increase occurred between three-digit sectors (Figure C6, Panel A).

In additional tests, we examine whether excluding those sectors and firms most likely to be affected by domestic outsourcing decreases the expansion of the age wage gap. Specifically, we drop all workers in those three-digit sectors identified by Goldschmidt and Schmieder (2017) as primary recipients of domestically outsourced jobs, as well as all workers employed by firms that have sold one or more business units (Figure C7, Panels B to D). Our main findings remain robust after these exclusions: the rank gap increased, and the majority of this increase occurred within sectors. Therefore, despite being an important labor-market phenomenon, domestic outsourcing does not appear to be a key driver of the growth in the age wage gap.[29]

[28] Goldschmidt and Schmieder (2017) documents that outsourced jobs have gradually moved to business-service firms concentrated in a limited number of sectors.

[29] This conclusion is consistent with the timing of domestic outsourcing. While domestic outsourcing became relevant during the 2000s, the widening of the age wage gap started at least two decades earlier.

## 6 Conclusions

This paper uses comprehensive administrative data on 38 million workers across 3.7 million firms in Italy and Germany, supplemented by survey data on 6.6 million workers from fourteen high-income countries. It demonstrates that over the past four decades, wages of older workers have been growing at a much faster rate than those of younger workers. In Italy, for instance, the wage gap between workers over 55 and those under 35 grew by 96 percent between 1985 and 2019, while in the United States it increased by 61 percent between 1979 and 2018.

Our analysis underscores the importance of negative career spillovers in this context (Bianchi et al., 2023). In a frictional labor market, characterized by costly worker-firm separations and firm-level constraints on creating new higher-ranked positions, a growing population of older workers and delayed retirements are compatible with older workers accruing more seniority, advancing further along organizational hierarchies, and maintaining higher-ranked jobs for longer periods. In turn, the increased presence of older workers at the top of firms' hierarchies hampers the career progression of younger workers.

We highlight five main findings describing the existence of these negative career spillovers. First, the expanding age wage gap primarily arises from the increasing difficulty experienced by younger workers, in contrast to older workers, in reaching the top segments of the wage distribution and higher-ranked job levels. Here, we demonstrate that the predominant factor in the growth of the age wage gap is not older workers extending their preexisting wage lead, but rather their surpassing of younger workers in the wage distribution. Second, in line with greater entrenchment of older workers at the top, younger workers enter the labor market at progressively lower segments of the wage distribution and experience lower wage growth for many years after entry. Third, older workers are prolonging their careers for longer periods in higher-paying firms. Within these firms, congestion has increased the most, pushing both younger and older workers, on average, toward lower portions of the wage distribution. Because this effect is more pronounced for younger workers, it therefore widens the age wage gap even within firms with more severe congestion. Fourth, the entrenchment of older workers in higher-paying firms makes it increasingly difficult for younger workers to secure any employment at all in these firms. Consequently, younger workers, confined to lower-paying firms and facing slower career progression, resort more frequently to turnover for career advancement, despite declining financial gains from these events. Fifth, as one would expect from negative career spillovers, the growth in the age wage gap is larger within firms that face more binding constraints on adding higher-ranked positions to their organizational hierarchies.

In conclusion, labor markets have witnessed a major wage transfer from younger to older workers. Future research should investigate the potential long-term implications of negative career spillovers beyond slowed career progression for younger workers. For example, lower early-career wages may deter some workers from purchasing durables, investing in real estate, or starting families, decisions that cannot always be deferred until later career stages.

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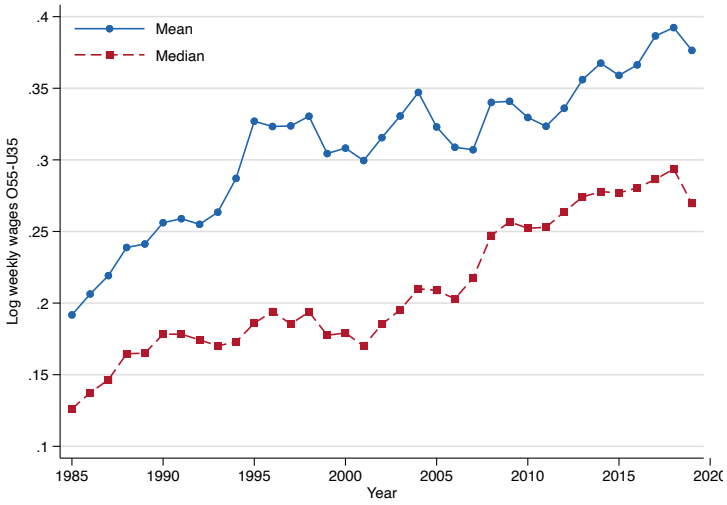
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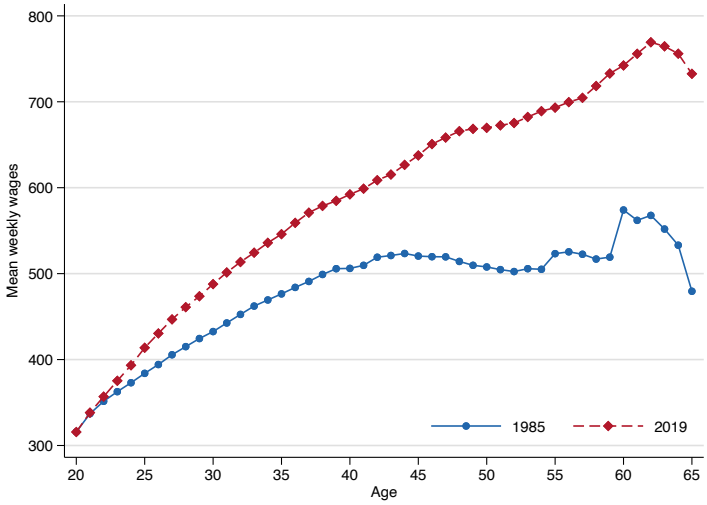
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# Figures and Tables

**Figure 1:** Age Gap in Weekly Wages



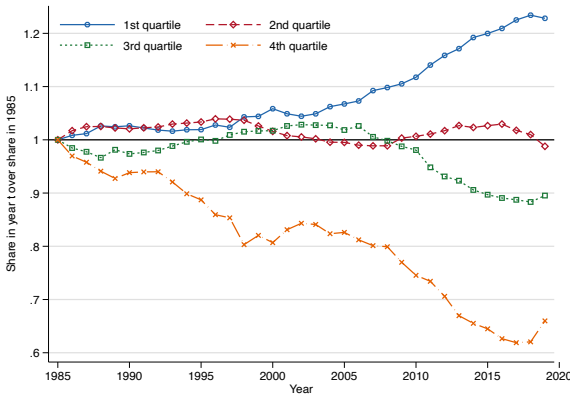

Panel A: Gap in log mean and median weekly wages



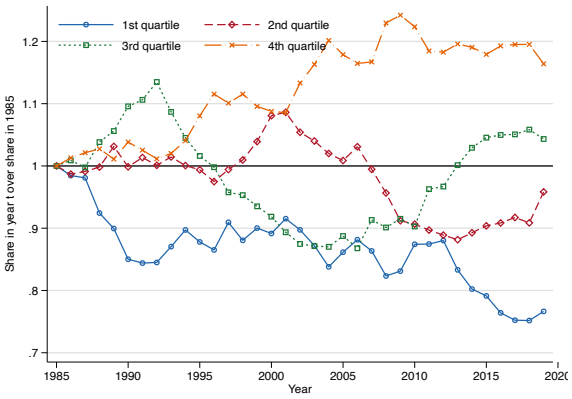

Panel B: Age profiles for mean weekly wages

*Notes:* Panel A plots the gap between the log weekly wages of O55 workers and the log weekly wages of U35 workers from 1985 to 2019 for both mean and median wages. Panel B plots the mean real weekly wages (not logged) by age in 1985 and 2019.
*Sources:* In each year, the data pool information about all workers who were at least 16 years old, had worked at least six months, had earned strictly positive wages, had full-time contracts, and had not retired by December 31. Database: UNIEMENS, Istituto Nazionale della Previdenza Sociale (Italy).

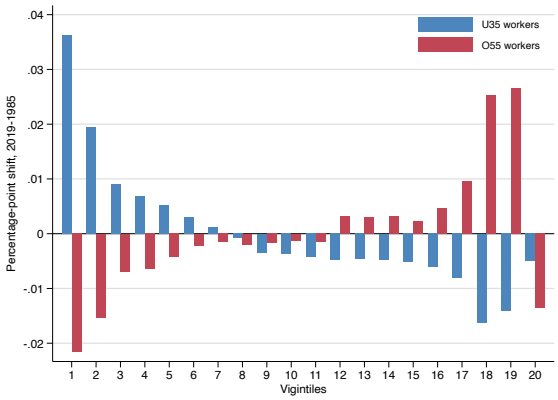
**Figure 2:** Positions in the Wage Distribution



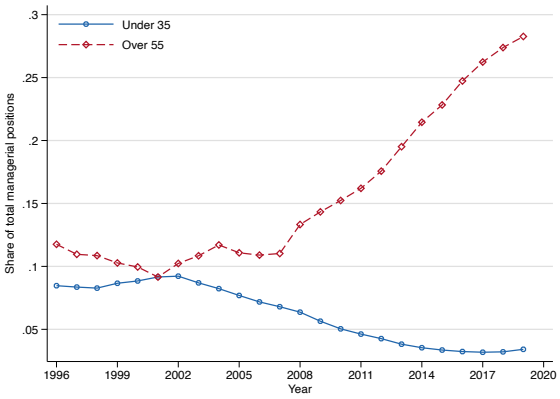

Panel A: U35 workers, quartiles




Panel B: O55 workers, quartiles




Panel C: Vigintiles

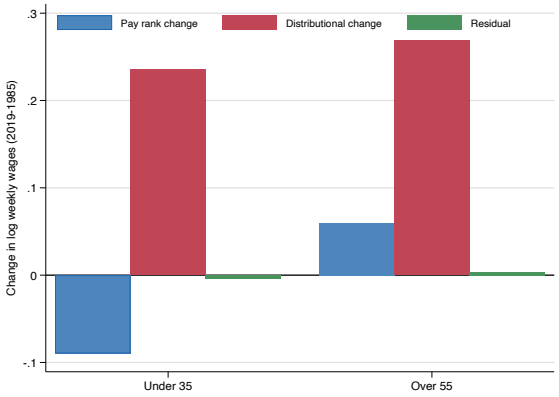



Panel D: Share of managerial jobs

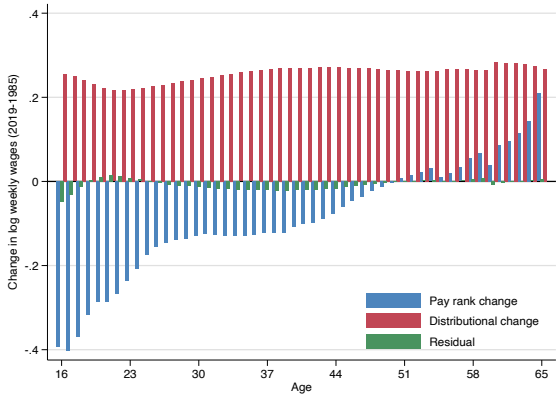
*Notes:* Panel A (B) shows the ratio between the share of U35 (O55) workers in each quartile in year $t$ and the share of U35 (O55) workers in the same quartile in 1985. Panel C plots the percentage-point difference in the share of U35 and O55 workers in each vigintile from 1985 to 2019. Panel D plots the share of total managerial jobs held by U35 and O55 workers for each year between 1996 (first year available) and 2019.

*Sources:* In each year, the data pool information about all workers who were at least 16 years old, had worked at least six months, had earned strictly positive wages, had full-time contracts, and had not retired by December 31. Database: UNIEMENS, Istituto Nazionale della Previdenza Sociale (Italy).

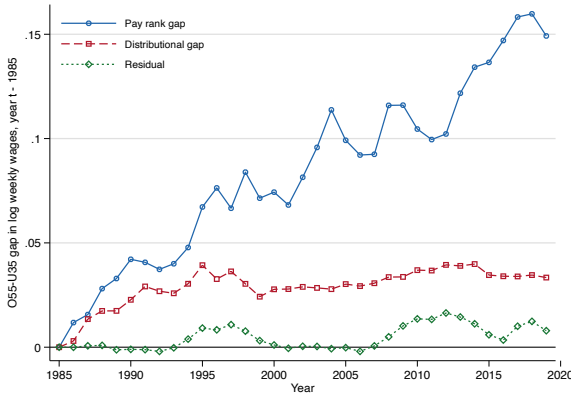
**Figure 3:** The Rank Change in Weekly Wages




Panel A: U35 and O55 workers, 2019-1985



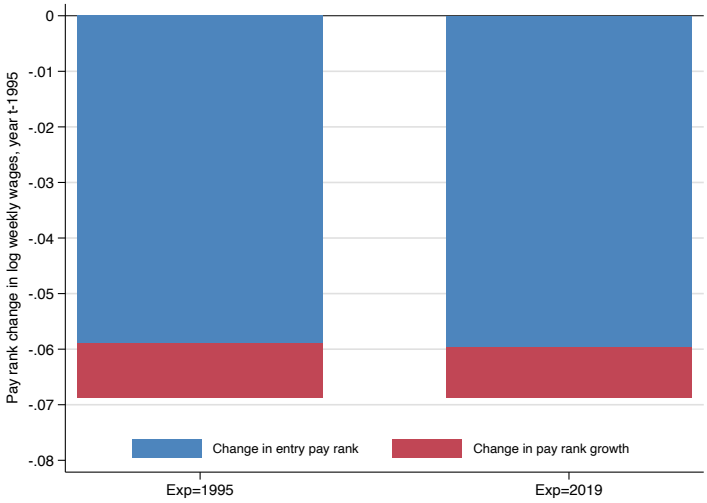

Panel B: All age groups, 2019-1985



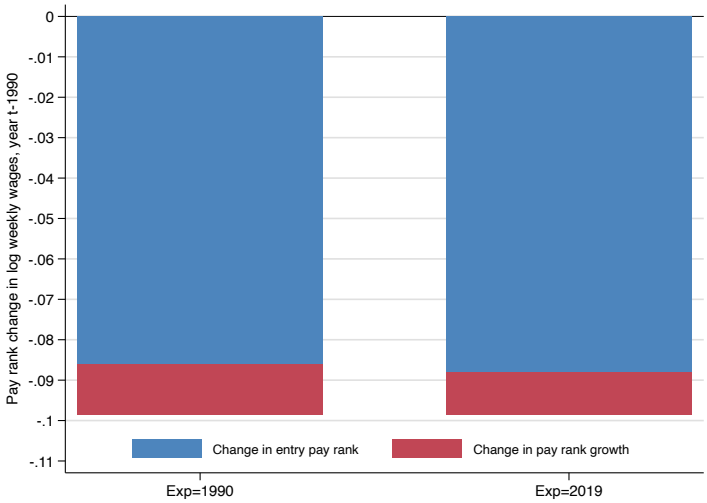

Panel C: O55 workers - U35 workers, $t \in [1986, 2019] - 1985$

*Notes:* Panel A shows the decomposition of the change in the mean log weekly wages between 1985 and 2019 into the three components of Equation (2) for under-35 (U35) workers and over-55 (O55) workers. Panel B shows the same decomposition for individual age groups. Panel C shows the same decomposition for the change in the age pay gap between O55 and U35 workers from 1985 to each year $t \in [1986, 2019]$.
*Sources:* In each year, the data pool information about all workers who were at least 16 years old, had worked at least six months, had earned strictly positive wages, had full-time contracts, and had not retired by December 31. Database: UNIEMENS, Istituto Nazionale della Previdenza Sociale (Italy).

**Figure 4:** Entry Pay Rank and Pay Rank Growth



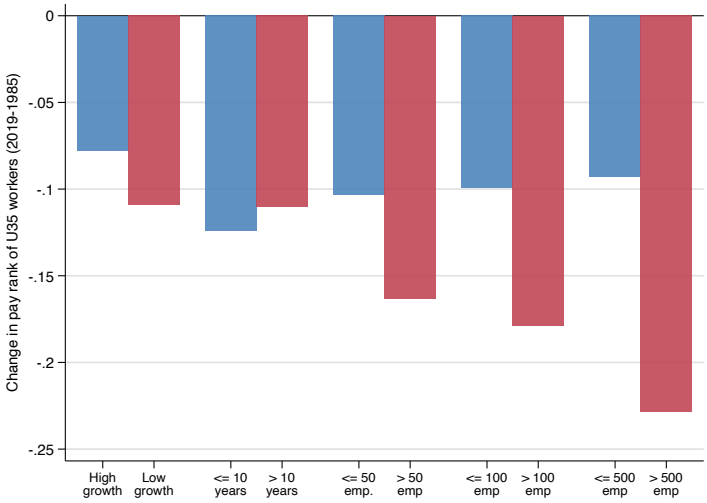

Panel A: U35 workers, 2019-1995



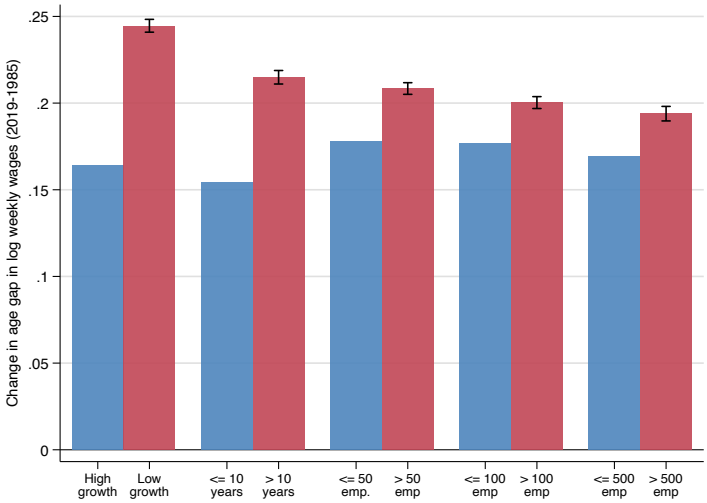

Panel B: U30 workers, 2019-1990

*Notes:* Panel A shows the decomposition of rank change in the distribution of log weekly wages for U35 worker from 1995 to 2019 into two components: (i) the change in pay rank at labor-market entry and (ii) the change in pay rank growth between labor-market entry and 2019 (Equation (3)). It shows this decomposition under two scenarios: in the first, the experience composition of U35 workers is kept fixed in 1995 (exp=1995), while in the second, it is kept fixed in 2019 (exp=2019). Panel B replicates the decomposition in Panel A for U30 workers between 1990 and 2019.
*Sources:* In each year, the data pool information about all workers who were at least 16 years old, had worked at least six months, had earned strictly positive wages, had full-time contracts, and had not retired by December 31. Database: UNIEMENS, Istituto Nazionale della Previdenza Sociale (Italy).

**Figure 5:** Age Pay Gap Across Different Firms




Panel A: Change in pay rank of U35 workers

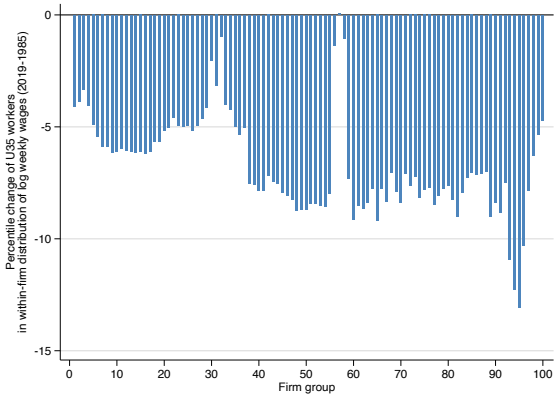



Panel B: Change in age pay gap

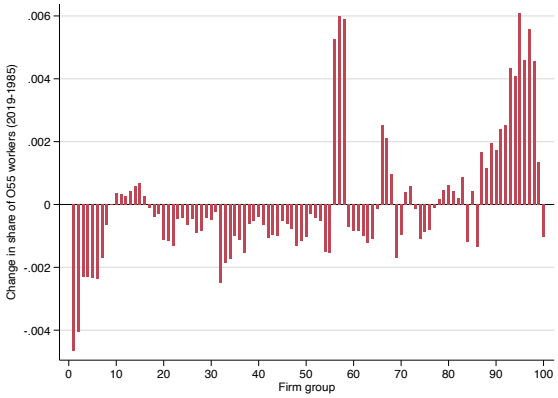
*Notes:* Panel A depicts the change in the pay rank of U35 workers in the distribution of log weekly wages (Equation (2)) across different categories of firms. "High growth" and "Low growth" refer to firms' rates of workforce growth. We first compute the mean yearly employment growth within a three-year window (from $t-3$ to $t$) for each firm and year in the sample. Firms with below-median mean employment growth are categorized as low-growth firms, while firms with above-median mean employment growth are high-growth firms. We also divide firms based on their age and workforce size. Panel B repeats the same analysis for the total change in the age pay gap between O55 workers and U35 workers. For each firm categorization, the vertical bars identify 95 percent confidence intervals of the difference between the two group means

*Sources:* In each year, the data pool information about all workers who were at least 16 years old, had worked at least six months, had earned strictly positive wages, had full-time contracts, and had not retired by December 31. Database: UNIEMENS, Istituto Nazionale della Previdenza Sociale (INPS).

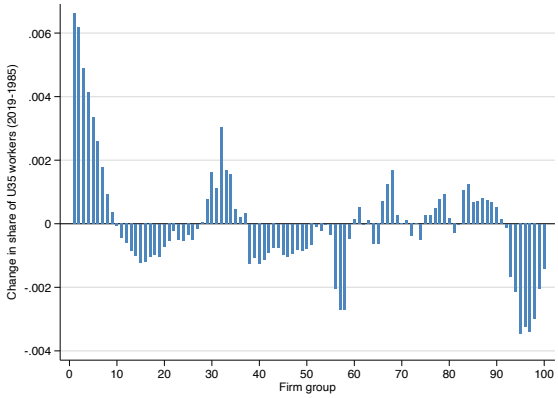
**Figure 6:** Distribution of Workers Within and Between Firms




Panel A: Position of U35 workers




Panel B: Share of O55 workers




Panel C: Share of U35 workers

*Notes:* Firm groups are one hundred groups that have the same number of workers and are ordered in ascending mean firm pay. Panel A shows the mean change in the percentile of U35 workers within the pay distribution of their firm group from 1985 to 2019. Panel B (Panel C) shows the change in O55 (U35) workers for each firm group from 1985 to 2019. To limit noise, the displayed values are averages computed using each group and its two adjacent firm groups (one in the case of the first and last group).
*Sources:* In each year, the data pool information about all workers who were at least 16 years old, had worked at least six months, had earned strictly positive wages, had full-time contracts, and had not retired by December 31. Database: UNIEMENS, Istituto Nazionale della Previdenza Sociale (Italy).

# Appendix - For Online Publication

## A Data Appendix

### A.1 Italian Administrative Data

We use data on the Italian labor market between 1985 and 2019 that are provided by the Italian Social Security Institute (INPS). This dataset consists of matched employer–employee records for the whole population of private-sector, nonagricultural firms with at least one salaried employee. The dataset combines individual-level information about workers, such as age and other demographic characteristics, wage, type of contract (full-time vs. part-time, open-ended vs. temporary), with information about the firm, such as sector, location, and age.

This dataset could be extended to include all years between 1974 and 1984 at the expense of having more limited information on the matching between workers and firms. Due to the fact that the empirical analysis relies on having detailed information on the matching between workers and firms, we decided to focus on the post-1985 years. Figure A1 shows that the increase in the age pay gap followed a similar trend just before and after 1985, indicating that the exclusion of the earlier years is not likely to bias the analysis.

The INPS dataset represents a comprehensive summary of all the labor-market events that happened during a calendar year. For example, for the workers who moved to a different firm, the dataset display two rows in the year of their move: one describes the contract with the "old" firm they left, while the other describes the contract with the "new" firm they joined. Similarly, for workers who received major internal promotions, the dataset display two rows in the year of their promotions: one describes the contract with the "old" pre-promotion position, while the other describes the contract with the "new" post-promotion position.

For the purpose of the analysis, we need to reduce this very rich dataset with multiple worker-year observations to a more streamlined dataset with unique worker-year pairings. As it is common in this branch of the literature, we always keep the information associated with the spell with the highest wage.

Moreover, we restrict each year of data to workers who (i) were at least 16 years old, (ii) had worked at least six months, (iii) had earned strictly positive wages, (iv) held full-time contracts, and (v) did not retire within that year. We impose these restrictions to weed out workers with very short-lived job spells.

Next, we create two main wage variables. First, we create the total yearly labor earnings by summing the wages of all working spells associated with each worker in a year. In other words, although we process the data by retaining only the spell with the highest wage, the yearly earnings pool information from all working spells that are available in the raw employer-employee data. Second, we create a variable that is closer to pay rates: weekly wages. We compute them by dividing the labor earnings by the number of weeks in which each employee worked. The number of working weeks is a core input in the computation of the yearly contributions owed by each worker to Social Security. Therefore, this variable tends to have a low incidence of missing values and measurement error. The weekly-wage variable uses information that comes exclusively from the working spell that we retained, that is, the spell with the highest wage during the year. Both measures of labor earnings are expressed in 2015 euros using the conversion tables prepared by the OECD.[30]

Unlike many administrative data providers in other countries, INPS does not winsorize earnings above the Social Security earnings maximum. The consequence is that the distribution of wages

[30] The tables can be downloaded from https://web.archive.org/web/20201109004157/https://data.oecd.org/price/inflation-cpi.htm.

tend to be fairly skewed, due to the presence of extreme outliers. For this reason, we winsorized both weekly wages and yearly earnings at the 99.9$^{\text{th}}$ percentile. Even after this winsorization, yearly earnings have very low values on the left tail of their distribution, indicating that our previous process was not able to weed out all short and inconsequential working spells. For this reason, we cap the minimum of yearly earnings at €3,000 in real terms.

## A.2 German Administrative Data

The data on the German labor market are available between 1996 and 2017 and are provided by the Research Data Centre (FDZ) of the Federal Employment Agency (BA) at the Institute for Employment Research (IAB). We employ the Linked Employer-Employee Data from the *LIAB Cross-Sectional Model 2* (LIAB).[31] This dataset combines information from the IAB Establishment Panel with information from the Integrated Employment Biographies (IEB).[32] The former is an annual representative survey of establishments, while the latter contains information on all workers subject to Social Security taxation. The LIAB dataset matches the individual biographies from the IEB to the sample of surveyed establishments in the IAB Establishment Panel.[33]

The LIAB has two important characteristics. First, information on employment and wages is available every year at the single reference date of June 30$^{\text{th}}$. Therefore, the data represents a static snapshot of the labor market, rather than a comprehensive summary of all labor-market events. Second, although the data is available starting in 1993, the IAB Establishment Panel covers both East and West Germany starting only in 1996. For this reason, we focus on the period between 1996 and 2017 to avoid creating inconsistent time series.

For the purpose of our analysis, we have access to the variables coming from the Employee-History (BeH) module, which collects annual and end-of-employment notifications submitted to the Social Security Agencies about employees covered by social security and employees in marginal part-time employment. Information on temporary contract workers is available only starting in 2011.

To create a dataset that is as close as possible to the Italian one, we select employees who (i) were between 16 years old and 75 years old, (ii) had a full-time contract, and (iii) had earned strictly positive wages.[34] These restrictions reduce the sample from 12,451,266 workers to 8,865,294 workers.

As we discussed in Section A.1 for the Italian data, workers may appear more than once in a given year if they worked for more than one firm. We reduce the data to a single observation per worker in each year using the following procedure. For each worker, we compute earnings in a given job spell multiplying the daily wage by the number of tenure days accumulated in the first semester of the year. We then select for each worker the job spell with the highest earnings in the year, and we attribute to the worker the daily wage earned in that spell. It should be noted that nominal earnings are top-coded at the Social Security earnings maximum, the threshold over which contributions to the Social Security are not owed. The cap varies from year to year, but is usually close to the 95$^{\text{th}}$ percentile. Finally, daily wages are expressed in 2015 euros using the conversion tables prepared by the OECD.

[31] Documentation can be fount at https://fdz.iab.de/en/Integrated_Establishment_and_Individual_Data/LIAB.aspx.

[32] Documentation on the IAB Establishment Panel is available at https://fdz.iab.de/en/FDZ_Establishment_Data/IAB_Establishment_Panel/IABBP_9319.aspx.

[33] The IAB Establishment Panel covers between 4,265 and 16,000 establishments per year.

[34] Workers who are more than 75 years old are automatically excluded by the data provider.

## A.3 Survey Data for Other Countries

In this section, we provide more information about the survey data that we used to measure the age wage gap in all other countries. The data source is the Luxembourg Income Study (LIS) database, which we last accessed on April 14, 2023 at https://www.lisdatacenter.org/. The LIS database aggregates and harmonizes heterogeneous survey data coming from many different countries. A full list of the original data sources is in the notes of Table A1. Out of all the available countries in the LIS database, we focus on fourteen high-income economies with sufficiently long time series, a large number of observations, and stable sample sizes: Australia, Canada, Denmark, Finland, France, Germany, Greece, Israel, Netherlands, Norway, Spain, Switzerland, United Kingdom, and United States.[35]

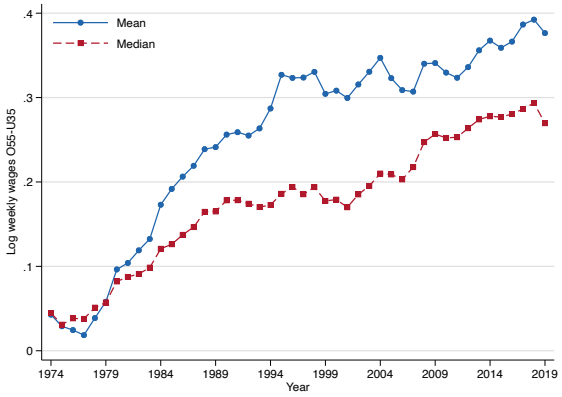
In the analysis, we compute the age pay gap using the only wage variable that is consistently available across survey waves and countries: yearly labor earnings (`pilabour`). Before doing so, we convert nominal yearly labor earnings for all countries to 2011 purchasing-power-parity US dollars, using the conversion tables prepared by LIS ( https://www.lisdatacenter.org/resources/ppp-deflators/?highlight=ppp).

Whenever possible, we apply the same sample restrictions used on the administrative data from Italy and Germany. Specifically, we restrict each year of data to workers who (i) were at least 16 years old, (ii) had earned strictly positive wages, (iii) were employees, (iv) had a full-time contract, and (v) had worked at least 20 weeks during the year. Restrictions (i) and (ii) can be imposed in every country and year, while restrictions (iii) to (v) require variables that are not available in every country. Table A1 lists all cross-country differences in the construction of the sample.

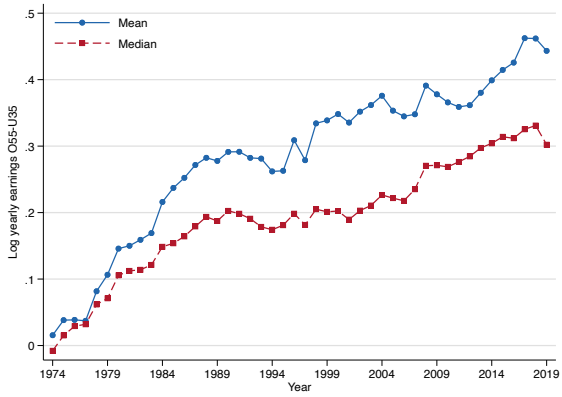
Finally, it should be noted that the LIS database is structured as repeated cross sections. Therefore, it is not possible to use the LIS data to follow the same workers over time. Moreover, this data source never matches workers to firms.

[35] We initially considered nineteen high-income countries with long time series: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Israel, Italy, Netherlands, Norway, Spain, Sweden, Switzerland, United Kingdom, and United States. We dropped Austria, Belgium, Ireland, and Italy because they had a small number of U35 and O55 workers in each wave (on average, less than 1,000 people per wave). Moreover, we dropped some early survey waves for Australia, France, Norway, Spain due to harmonization problems with the more recent years (for these countries, we kept all years that followed the last time their sample size shrank by at least 30 percent from the previous wave).

**Figure A1:** The Age Gap in Italy from 1974




Panel A: Gap in log mean and median weekly wages




Panel B: Gap in log mean and median yearly earnings

*Notes:* Panel A plots the gap between the log weekly wages of O55 workers and the log weekly wages of U35 workers between 1974 and 2019 for both mean and median wages. Panel B repeats this analysis for yearly labor earnings, rather than for weekly wages.
*Sources:* In each year, the data pool information about all workers who were at least 16 years old, had worked at least six months, had earned strictly positive wages, had full-time contracts, and had not retired by December 31. Database: UNIEMENS, Istituto Nazionale della Previdenza Sociale (Italy).

**Table A1:** Characteristics of Data Sources

| | # available years | # observations | # workers | # firms | Wage definition | Restrict to employees | Restrict to full time | Restrict working weeks |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Panel A: Employer-employee administrative data | | | | | | | | |
| Italy (1985-2019) | 35 | 312,065,728 | 28,911,242 | 3,532,905 | Weekly | Yes | Yes | Yes |
| Germany (1996-2017) | 22 | 35,092,712 | 8,865,294 | 127,782 | Daily | Yes | Yes | No |
| Panel B: Survey data from the Luxembourg Income Study (LIS) Database | | | | | | | | |
| Australia (1995-2018) | 9 | 74,817 | - | - | Yearly | Yes | Yes | No |
| Canada (1973-2018) | 41 | 1,082,370 | - | - | Yearly | Yes | Yes | Yes |
| Denmark (1987-2016) | 9 | 540,889 | - | - | Yearly | Yes | No | No |
| Finland (1987-2016) | 9 | 79,119 | - | - | Yearly | Yes | No | Yes |
| France (2002-2018) | 17 | 488,398 | - | - | Yearly | Yes | Yes | No |
| Germany (1994-2018) | 25 | 198,138 | - | - | Yearly | Yes | Yes | Yes |
| Greece (1995-2016) | 7 | 25,887 | - | - | Yearly | Yes | No | No |
| Israel (1979-2018) | 22 | 162,407 | - | - | Yearly | Yes | Yes | No |
| Netherlands (1983-2018) | 13 | 64,589 | - | - | Yearly | Yes | Yes | No |
| Norway (1986-2016) | 9 | 894,042 | - | - | Yearly | Yes | No | No |
| Spain (1993-2018) | 23 | 158,300 | - | - | Yearly | Yes | Yes | Yes |
| Switzerland (1982-2018) | 15 | 74,382 | - | - | Yearly | Yes | Yes | No |
| United Kingdom (1979-2018) | 40 | 468,823 | - | - | Yearly | Yes | Yes | No |
| United States (1979-2018) | 40 | 2,265,013 | - | - | Yearly | Yes | Yes | Yes |

*Sources for Italy:* Database UNIEMENS, Istituto Nazionale della Previdenza Sociale (INPS). *Sources for Germany:* The German data come from the LIAB Linked Employer-Employee Dataset provided by the Institute for Employment Research. *Sources for Australia:* Survey of Income and Housing, Household Expenditure Survey (2004); Survey of Income and Housing (all other years). *Sources for Canada:* Survey of Consumer Finances (1973-1995); Survey of Labour and Income Dynamics (1996-2011); Canadian Income Survey (2012 and later). *Sources for Denmark:* sample based on administrative records; The Danish National Centre for Social Research, Statistics Denmark, Ministry of Finance, Ministry of Economic Affairs and the Interior, Ministry of Taxation. *Sources for Finland:* Income Distribution Survey (before 2004); SILC (2004 onwards). *Sources for France:* Tax and Social Incomes Survey. *Sources for Germany (LIS):* German Socio-Economic Panel. *Sources for Greece:* ECHP (1995, 2000); SILC (all other years). *Sources for Israel:* Household Expenditure Survey. *Sources for Netherlands:* Amenities and Services Utilization Survey (1983, 1987, 1990); Socio-Economic Panel Survey (1993, 1999); SILC (all other years). *Sources for Norway:* Income Distribution Survey (2004 and before); Household Income Statistics (2007 and after). *Sources for Spain*: European Community Household Panel (1993-2000); SILC (2004 and later. *Sources for Switzerland:* Swiss Income and Wealth Survey (1982); National Poverty Study (1992); Income and Expenditure Survey (2000, 2002, 2004); SILC (all other years). *Sources for United Kingdom:* Family Expenditure Survey (1991 and earlier); Family Resources Survey (1994 and later). *Sources for United States:* CPS March Supplement (2001 and before); CPS Annual Social and Economic Supplement (2002 and later).

**Table A2:** Empirical Analysis and Data Sources

| | Δ wage gap | Rank gap vs. distributional gap | Between/within firms | Entry rank vs. Rank growth | Firm Heterogeneity | Workforce composition |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Panel A: Employer-employee administrative data | | | | | | |
| Italy (1985-2019) | Yes | Yes | Yes | Yes | Yes | Yes |
| Germany (1996-2017) | Yes | Yes | Yes | No (no info on entry wage) | Yes (partial) | Yes |
| Panel B: Survey data from the Luxembourg Income Study (LIS) Database | | | | | | |
| Australia (1995-2018) | Yes | Yes | No (no firm info) | No (no info on entry wage) | No (no firm info) | Yes |
| Canada (1973-2018) | Yes | Yes | No (no firm info) | No (no info on entry wage) | No (no firm info) | Yes |
| Denmark (1987-2016) | Yes | Yes | No (no firm info) | No (no info on entry wage) | No (no firm info) | Yes |
| Finland (1987-2016) | Yes | Yes | No (no firm info) | No (no info on entry wage) | No (no firm info) | Yes |
| France (2002-2018) | Yes | Yes | No (no firm info) | No (no info on entry wage) | No (no firm info) | Yes |
| Germany (1994-2018) | Yes | Yes | No (no firm info) | No (no info on entry wage) | No (no firm info) | Yes |
| Greece (1995-2016) | Yes | Yes | No (no firm info) | No (no info on entry wage) | No (no firm info) | Yes |
| Israel (1979-2018) | Yes | Yes | No (no firm info) | No (no info on entry wage) | No (no firm info) | Yes |
| Netherlands (1983-2018) | Yes | Yes | No (no firm info) | No (no info on entry wage) | No (no firm info) | Yes |
| Norway (1986-2016) | Yes | Yes | No (no firm info) | No (no info on entry wage) | No (no firm info) | Yes |
| Spain (1993-2018) | Yes | Yes | No (no firm info) | No (no info on entry wage) | No (no firm info) | Yes |
| Switzerland (1982-2018) | Yes | Yes | No (no firm info) | No (no info on entry wage) | No (no firm info) | Yes |
| United Kingdom (1979-2018) | Yes | Yes | No (no firm info) | No (no info on entry wage) | No (no firm info) | Yes |
| United States (1979-2018) | Yes | Yes | No (no firm info) | No (no info on entry wage)- | No (no firm info) | Yes |

*Notes:* "No (no firm info)" means that the data source does not match workers to firms. "No (no info on entry wage)" means that the data source does not include any information on the entry year of most workers. This missing information prevents us from assigning the initial wage to most workers in the sample.

**Table A3:** Workforce Aging and Age Wage Gap

| | Change in mean worker age | | Level and change in age wage gap at the mean | | | | | | Change in age wage gap at various percentiles | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | last y. - first y. | | first year | 2007 - first y. | 2013 - first y. | last year - first year | | | last year - first year | | | | |
| | Δ years | Δ % | wage gap (log) | Δ wage gap (log) | Δ wage gap (log) | Δ wage gap (log) | Rank gap (%) | Distr. gap (%) | Perc. 10 (log) | Perc. 25 (log) | Median (log) | Perc. 75 (log) | Perc. 90 (log) |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) |
| Panel A: Employer-employee administrative data | | | | | | | | | | | | | |
| Italy (1985-2019) | 6.87 | 19.21 | 0.192 | 0.115 | 0.164 | 0.185 | 78.32 | 17.52 | 0.200 | 0.100 | 0.140 | 0.250 | 0.180 |
| Germany (1996-2017) | 3.44 | 8.67 | 0.282 | 0.201 | 0.127 | 0.101 | 55.83 | 28.04 | 0.010 | 0.340 | 0.100 | -0.010 | -0.020 |
| Panel B: Survey data from the Luxembourg Income Study (LIS) Database | | | | | | | | | | | | | |
| Australia (1995-2018) | 5.66 | 16.22 | 0.039 | 0.166 | 0.183 | 0.177 | 80.01 | 7.23 | -0.008 | 0.086 | 0.211 | 0.153 | 0.132 |
| Canada (1973-2018) | 0.92 | 2.38 | 0.040 | 0.379 | 0.227 | 0.174 | 77.02 | 4.89 | 0.229 | 0.212 | 0.150 | 0.193 | 0.187 |
| Denmark (1987-2016) | 6.45 | 17.33 | 0.157 | 0.252 | 0.321 | 0.185 | 136.71 | -9.54 | 0.300 | 0.226 | 0.131 | 0.135 | 0.146 |
| Finland (1987-2016) | 6.81 | 19.00 | 0.044 | 0.188 | 0.222 | 0.214 | 102.73 | 5.87 | 0.455 | 0.239 | 0.130 | 0.121 | 0.136 |
| France (2002-2018) | 2.24 | 5.74 | 0.374 | 0.062 | 0.002 | 0.029 | 40.36 | 45.44 | 0.260 | 0.062 | -0.014 | -0.041 | -0.037 |
| Germany (1994-2018) | 3.77 | 9.82 | 0.448 | 0.162 | 0.175 | 0.084 | 48.40 | 48.98 | 0.030 | 0.166 | 0.131 | -0.007 | 0.010 |
| Greece (1995-2016) | 2.95 | 7.51 | 0.278 | 0.294 | 0.218 | 0.180 | 100.75 | 3.40 | 0.130 | 0.202 | 0.202 | 0.206 | 0.206 |
| Israel (1979-2018) | -2.92 | -7.16 | 0.038 | 0.199 | 0.604 | 0.412 | 53.53 | 16.99 | 0.439 | 0.370 | 0.323 | 0.459 | 0.522 |
| Netherlands (1983-2018) | 3.40 | 9.09 | 0.314 | 0.380 | 0.428 | 0.226 | 7.69 | 73.48 | 0.555 | 0.259 | 0.077 | -0.022 | -0.009 |
| Norway (1986-2016) | 4.17 | 10.68 | 0.123 | 0.095 | 0.139 | 0.159 | 77.78 | 16.86 | 0.106 | 0.134 | 0.095 | 0.115 | 0.176 |
| Spain (1993-2018) | 4.98 | 12.88 | 0.189 | 0.265 | 0.330 | 0.509 | 60.99 | 15.56 | 0.668 | 0.532 | 0.391 | 0.444 | 0.440 |
| Switzerland (1982-2018) | 2.44 | 6.20 | 0.131 | 0.727 | 0.621 | 0.481 | 49.61 | 7.03 | 1.415 | 0.342 | 0.169 | 0.184 | 0.167 |
| United Kingdom (1979-2018) | 3.21 | 8.66 | 0.103 | 0.044 | 0.134 | 0.042 | 15.24 | 51.81 | -0.182 | -0.099 | 0.004 | 0.147 | 0.313 |
| United States (1979-2018) | 4.51 | 11.91 | 0.222 | 0.144 | 0.176 | 0.136 | 89.00 | 19.93 | 0.144 | 0.145 | 0.125 | 0.131 | 0.153 |

*Notes:* Columns 1 and 2 show the change in mean worker age. Column 3 shows the level of the age wage gap, the difference in mean log wages between O55 workers and U35 workers, at baseline. The next columns show the age wage gap's growth between the first available year for each country and 2007 (column 4; 2008 for AUS), 2013 (columns 5; 2014 for AUS), or the last available year for each country (column 6). Columns 7 and 8 refer to the decomposition in Equation (**??**). Columns 9 to 13 show the change in age wage gap at different percentiles. Table A1 provides more information about the wage variable and the sample restrictions in each country.
*Sources for Italy:* Database UNIEMENS, Istituto Nazionale della Previdenza Sociale (INPS). *Sources for Germany:* LIAB Linked Employer-Employee Dataset provided by the Institute for Employment Research. Details on the construction of these samples are in Appendix A.2. *Sources for LIS data:* Luxembourg Income Study (LIS) Database, which we last accessed on 04/14/2023 at https://www.lisdatacenter.org/. More details are in Appendix A.3.

# B Proofs

**Representative firm.** The firm chooses $l_{y,t}$, $l_{y,b}$, and $x_o$. The choice of $l_{y,b}$ leads to the following first order condition:

$$w_{y,b} = Y_{L_y}\theta_{y,b}, \tag{B.1}$$

where $Y_{L_y} = \frac{\partial Y(L_y,L_o)}{\partial L_y}$. The choice of $l_{y,t}$ leads to the following first order condition:

$$w_{y,t} = Y_{L_y}\theta_{y,t} - (1+\lambda)\,\kappa. \tag{B.2}$$

where $\lambda$ is the multiplier on the organizational constraint. The choice of $x_o$ leads to the following first order condition:

$$Y_{L_o}\left(\theta_{o,b} - \theta_{o,t}\right) + (\mu_o - 1)\,w_{o,b} + (1+\lambda)\left(\kappa - c_{x_o}\right) = 0, \tag{B.3}$$

where $Y_{L_o} = \frac{\partial Y(L_y,L_o)}{\partial L_o}$ and $c_{x_o} = \frac{\partial c(x_o)}{\partial x_o}$.

**Proposition 1.** Under the scenario in which the constraint is binding, we study how an increase in the supply of older workers in the top job affects the average wage of younger workers in equilibrium ($\bar{w}_y = \frac{l_{y,b}}{l_y}w_{y,b} + \frac{l_{y,t}}{l_y}w_{y,t}$):

$$\begin{aligned}
\frac{\partial \bar{w}_y}{\partial l_{o,t}^{-1}} &= \frac{\partial\left(\frac{l_{y,b}}{l_y}w_{y,b} + \frac{l_{y,t}}{l_y}w_{y,t}\right)}{\partial l_{o,t}^{-1}} \\
&= \frac{1}{l_y}\frac{\partial l_{y,t}}{\partial l_{o,t}^{-1}}(\mu_y - 1)\,w_{y,b} + \frac{l_{y,b}}{l_y}\frac{\partial w_{y,b}}{\partial l_{o,t}^{-1}} + \frac{l_{y,t}}{l_y}\frac{\partial w_{y,t}}{\partial l_{o,t}^{-1}} \\
&= \frac{1}{l_y}\frac{\partial l_{y,t}}{\partial l_{o,t}^{-1}}(\mu_y - 1)\,w_{y,b} + \frac{l_{y,b}}{l_y}\frac{\partial w_{y,b}}{\partial l_{o,t}^{-1}} + \frac{l_{y,t}}{l_y}\frac{\partial \mu_y w_{y,b}}{\partial l_{o,t}^{-1}} \\
&= \frac{1}{l_y}\frac{\partial l_{y,t}}{\partial l_{o,t}^{-1}}(\mu_y - 1)\,w_{y,b} + \frac{l_{y,b}}{l_y}\left(Y_{L_yL_y}\theta_{y,b}\frac{\partial l_{y,t}}{\partial l_{o,t}^{-1}}(\theta_{y,t} - \theta_{y,b}) + Y_{L_yL_o}\theta_{y,b}\rho_t\theta_{o,t}\right) \\
&+ \frac{l_{y,t}}{l_y}\mu_y\left(Y_{L_yL_y}\theta_{y,b}\frac{\partial l_{y,t}}{\partial l_{o,t}^{-1}}(\theta_{y,t} - \theta_{y,b}) + Y_{L_yL_o}\theta_{y,b}\rho_t\theta_{o,t}\right) \\
&= \underbrace{\frac{1}{l_y}\frac{\partial l_{y,t}}{\partial l_{o,t}^{-1}}(\mu_y - 1)\,w_{y,b}}_{\text{Crowding out}} \\
&+ \underbrace{Y_{L_yL_o}\frac{1}{l_y}\theta_{y,b}\rho_t\theta_{o,t}\left(l_{y,b} + \mu_y l_{y,t}\right) - Y_{L_yL_y}\frac{1}{l_y}\rho_t\theta_{y,b}\left(\theta_{y,t} - \theta_{y,b}\right)\left(l_{y,b} + \mu_y l_{y,t}\right)}_{\text{Relative labor supply}},
\end{aligned}$$

where $\frac{\partial l_{y,t}}{\partial l_{o,t}^{-1}} = -\rho_t + \partial x_o/\partial l_{o,t}^{-1} < 0$ stems from the binding organizational constraint ( $l_{y,t} = \frac{K - c(x_o)}{\kappa} - \rho_t l_{o,t}^{-1} - x_o$) and the assumption that $\partial x_o/\partial l_{o,t}^{-1} < \rho_t$. Given that $Y_{L_yL_o} = \frac{\partial^2 Y(L_y,L_o)}{\partial L_y \partial L_o} > 0$ and $Y_{L_yL_y} = \frac{\partial^2 Y(L_y,L_o)}{\partial L_y \partial L_y} < 0$, the crowding-out component is negative, while the relative-labor-supply component is positive.

If we consider a change in $\rho_t$,the retention rate of older workers from period $-1$, we reach very similar conclusions:

$$
\begin{aligned}
\frac{\partial \bar{w}_y}{\partial \rho_t} &= \frac{\partial \left( \frac{l_{y,b}}{l_y} w_{y,b} + \frac{l_{y,t}}{l_y} w_{y,t} \right)}{\partial \rho_t} \\
&= \frac{1}{l_y} \frac{\partial l_{y,t}}{\partial \rho_t} \left( \mu_y - 1 \right) w_{y,b} + \frac{l_{y,b}}{l_y} \frac{\partial w_{y,b}}{\partial \rho_t} + \frac{l_{y,t}}{l_y} \frac{\partial \mu_y w_{y,b}}{\partial \rho_t} \\
&= \underbrace{\frac{1}{l_y} \frac{\partial l_{y,t}}{\partial \rho_t} \left( \mu_y - 1 \right) w_{y,b}}_{\text{Crowding out}} \\
&+ \underbrace{Y_{L_y L_o} \frac{1}{l_y} \theta_{y,b} l_{o,t}^{-1} \theta_{o,t} \left( l_{y,b} + \mu_y l_{y,t} \right) - Y_{L_y L_y} \frac{1}{l_y} l_{o,t}^{-1} \theta_{y,b} \left( \theta_{y,t} - \theta_{y,b} \right) \left( l_{y,b} + \mu_y l_{y,t} \right)}_{\text{Relative labor supply}},
\end{aligned}
$$

where $\frac{\partial l_{y,t}}{\partial \rho_t} = -l_{o,t}^{-1} + \partial x_o / \partial \rho_t < 0$ if we assume that the marginal change in demotions is lower than the marginal increase in the number of older legacy workers ($\partial x_o / \partial \rho l_t < l_{o,t}^{-1}$). In other words, negative career spillovers require that firms are not able to fully undo the consequences of workforce aging at the top by demoting excess legacy workers.

**Proposition 2.** When the constraint is not binding ($NB$), $\lambda = 0$. Then, $w_{y,b}^{NB}$ is equal to the marginal product of labor (of younger workers) in the bottom job, $w_{y,t}^{NB} = \mu_y w_{y,b}^{NB}$, and the ratio between the marginal product of labor in the top and bottom job is equal to $\mu_y$. Without loss of generality, we can assume that, when the organizational constraint is not binding, the firm sets $x_o^{NB} = 0$. Here, we assume that the firm optimized the allocation of older workers between the two job levels in period $-1$. Therefore, in the absence of an external financial constraint, it does not have reasons to change the number of legacy workers in the top job in period 0.

When the constraint is binding ($B$), $\lambda > 0$. Relative to the nonbinding scenario, the firm assigns fewer younger workers to the top job: $l_{y,t}^{B} < l_{y,t}^{NB}$. We can see this result from Equation (B.2). We replace $w_{y,t}$ with $\mu_y Y_{L_y} \theta_{y,b}$, and then rewrite Equation (B.2) as follows: $Y_{L_y} \left( \theta_{y,t} - \mu_y \theta_{y,b} \right) - \left( 1 + \lambda \right) \kappa = 0$. Since the second term becomes more negative when $\lambda > 0$, the first term needs to compensate by becoming more positive. Due to the concavity of the production function, a larger $Y_{L_y}$ requires a lower $L_y$. Given that the model involves full employment, a lower $L_y$ requires $l_{y,t}^{B} < l_{y,t}^{NB}$ and $l_{y,b}^{B} > l_{y,b}^{NB}$.

We apply a similar reasoning to assess in what direction $x_o^B$ is changing with respect to $x_o^{NB}$. If $\kappa - c_{x_o} > 0$ (the marginal cost of maintaining a top job is larger than the marginal cost of a demotion), the third component in Equation (B.3) becomes more positive when $\lambda$ becomes positive. In period 1, the second component is fixed. Hence, the first component needs to adjust by becoming more negative. A larger $Y_{L_o}$ requires a lower $L_o$, which in period 1 can be achieved by choosing $x_o^B > x_o^{NB} = 0$. If $\kappa - c_{x_o} < 0$, the firm would like to change $x_o$ in the opposite direction, but $x_o$ cannot be negative. Hence, in this scenario, $x_o^B = x_o^{NB} = 0$.

Beyond the comparison between the nonbinding and binding scenario, the same conclusions can be drawn when the binding constraint becomes tighter (lower $K$). We can combine again the first two first order conditions into the following equation: $Y_{L_y} \left( \theta_{y,t} - \mu_y \theta_{y,b} \right) - \left( 1 + \lambda \right) \kappa = 0$. The Lagrangian multiplier is the shadow price of the organizational constraint, and is therefore decreasing with $K$. When $K$ decreases, the second term becomes more negative. Therefore, the first term needs to compensate by becoming more positive. Hence, $L_y$ decreases, leading to a lower $l_{y,t}^{B}$.

As an extension to the baseline model, we can rewrite the total amount of pre-production

resources that the firm can spend to maintain top jobs and demote legacy workers as a function of the aggregate growth rate of the economy: $K(\frac{A}{A^{-1}})$, where $A$ is either GDP or TFP, and $K_{A/A^{-1}} > 0$. A progressive decrease in the economic growth rate, such as that experienced by most high-income countries in the last four decades, would make the organizational constraint more binding, limiting employment opportunities in top jobs for younger workers.

**Heterogeneous firms.** The timing of the game is as follows. First, each firm receives legacy older workers from period $-1$. Then, each firm posts wage offers for its bottom and top jobs, and each younger worker joins the firm and job that maximizes her utility. Finally, the production is realized, and the firm makes payments to all workers.

The firm problem is to choose the wages in the top and bottom job in order to maximize its profits,

$$\max_{w_{y,t,f}, w_{y,b,f}} A_f Y\left(L_{y,f}, L_{o,f}\right) - \sum_{a=y,o} \sum_{j=t,b} w_{a,j,f} l_{a,j,f} - \kappa \cdot \left(l_{o,t,f} + l_{y,t,f}\right),$$

subject to

$$\kappa \cdot \left(l_{o,t,f} + l_{y,t,f}\right) \leq K_f.$$

Each firm $f$ also faces the following labor supply function for its job $j$:

$$l_{y,j,f} = \frac{\left(w_{y,j,f} X_{y,f}\right)^{\frac{1}{\sigma}}}{\sum_{f=1}^{F} \sum_{j \in \{t,b\}} \left(w_{y,j,f} X_{y,f}\right)^{\frac{1}{\sigma}}} l_y.$$

When a firm increases the wage paid in a given job, it anticipates the following change in labor supply:

$$\begin{aligned} \frac{\partial l_{y,j,f}}{\partial w_{y,j,f}} &= \frac{1}{\sigma} X_{y,f} \frac{\left(w_{y,j,f} X_{y,f}\right)^{\frac{1}{\sigma}-1}}{\sum_{f=1}^{F} \sum_{j \in \{t,b\}} \left(w_{y,j,f} X_{y,f}\right)^{\frac{1}{\sigma}}} l_y \\ &= \frac{1}{\sigma} \frac{l_{y,j,f}}{w_{y,j,f}} \end{aligned}$$

The denominator of the labor supply function does not change when the wage in firm $f$ and job $j$ changes because firms do not internalize the consequences of their own wage schedules on the market-wide level of wages. The firm's first order condition with respect to $w_{y,b,f}$ is:

$$\begin{aligned} A_f Y_{L_{y,f}} \theta_{y,b,f} \frac{1}{\sigma} \frac{l_{y,b,f}}{w_{y,b,f}} - w_{y,b,f} \frac{1}{\sigma} \frac{l_{y,b,f}}{w_{y,b,f}} - l_{y,b,f} &= 0 \\ w_{y,b,f} &= \underbrace{\frac{1}{1+\sigma}}_{\text{Markdown}} A_f Y_{L_{y,f}} \theta_{y,b,f}. \end{aligned}$$

The first order condition with respect to $w_{y,t,f}$ is:

$$\begin{aligned} A_f Y_{L_{y,f}} \theta_{y,t,f} \frac{1}{\sigma} \frac{l_{y,t,f}}{w_{y,t,f}} - w_{y,t,f} \frac{1}{\sigma} \frac{l_{y,t,f}}{w_{y,t,f}} - l_{y,t,f} & \\ -\kappa (1+\lambda_f) \frac{1}{\sigma} \frac{l_{y,t,f}}{w_{y,t,f}} &= 0 \\ w_{y,t,f} &= \underbrace{\frac{1}{1+\sigma}}_{\text{Markdown}} \left[ A_f Y_{L_{y,f}} \theta_{y,t,f} - \kappa (1+\lambda_f) \right]. \end{aligned}$$

In equilibrium, wages pay a markdown below the marginal product of labor in both the bottom and top job.

**Proposition 3.** The first part of Proposition 3 stems directly from the organizational constraint of each firm. When the constraint is binding, an increase in the number of older workers in top positions decreases the top slots that are available for younger workers. Here, we are assuming that the increase in the total number of older workers in the economy translates to increases in the number of older workers in the top jobs of all firms in the labor market. This effect is the crowding-out component that we already described in the setting with a representative firm.[36]

Moreover, it is still true that, although younger workers are more likely to hold lower-ranked positions, the overall effect of workforce aging on the mean wage of younger workers is ex-ante ambiguous. In fact, the relative-labor-supply effect is contributing to increase the mean wage of younger workers by raising their marginal product of labor in the bottom job. We can see this point by computing the derivative of younger workers' wages with respect to an increase in the number of older workers in the market.

The marginal change in the bottom wage is as follows:

$$\begin{aligned} \frac{\partial w_{y,b,f}}{\partial l_o} &= \frac{1}{1+\sigma} A_f \theta_{y,b,f} \left( Y_{L_{y,f} L_{o,f}} \frac{\partial L_{o,f}}{\partial l_o} + Y_{L_{y,f} L_{y,f}} \left( \frac{1}{\sigma} \frac{l_{y,b,f}}{w_{y,b,f}} \frac{\partial w_{y,b,f}}{\partial l_o} \theta_{y,b,f} + \frac{\partial l_{y,t,f}}{\partial l_o} \theta_{y,t,f} \right) \right) \\ &= \frac{\frac{1}{1+\sigma} A_f \theta_{y,b,f} \left( Y_{L_{y,f} L_{o,f}} \frac{\partial L_{o,f}}{\partial l_o} + Y_{L_{y,f} L_{y,f}} \frac{\partial l_{y,t,f}}{\partial l_o} \theta_{y,t,f} \right)}{1 - \frac{1}{1+\sigma} \frac{1}{\sigma} A_f \theta_{y,b,f}^2 Y_{L_{y,f} L_{y,f}} \frac{l_{y,b,f}}{w_{y,b,f}}} > 0. \end{aligned}$$

The marginal change in the top wage is as follows:

$$\begin{aligned} \frac{\partial w_{y,t,f}}{\partial l_o} &= \frac{1}{1+\sigma} A_f \theta_{y,t,f} \cdot \\ &\quad \left( Y_{L_{y,f} L_{o,f}} \frac{\partial L_{o,f}}{\partial l_o} + Y_{L_{y,f} L_{y,f}} \left( \frac{1}{\sigma} \frac{l_{y,b,f}}{w_{y,b,f}} \frac{\partial w_{y,b,f}}{\partial l_o} \theta_{y,b,f} + \frac{\partial l_{y,t,f}}{\partial l_o} \theta_{y,t,f} \right) - \frac{\kappa}{A_f \theta_{y,t,f}} \frac{\partial \lambda_f}{\partial l_o} \right) \\ &= \frac{\partial w_{y,b,f}}{\partial l_o} \frac{\theta_{y,t,f}}{\theta_{y,b,f}} \left( 1 - \frac{1}{1+\sigma} \frac{1}{\sigma} A_f \theta_{y,b,f}^2 Y_{L_{y,f} L_{y,f}} \frac{l_{y,b,f}}{w_{y,b,f}} \right) \\ &\quad + \frac{1}{1+\sigma} A_f \theta_{y,t,f} \left( Y_{L_{y,f} L_{y,f}} \left( \frac{1}{\sigma} \frac{l_{y,b,f}}{w_{y,b,f}} \frac{\partial w_{y,b,f}}{\partial l_o} \theta_{y,b,f} \right) - \frac{\kappa}{A_f \theta_{y,t,f}} \frac{\partial \lambda_f}{\partial l_o} \right) \\ &= \frac{\partial w_{y,b,f}}{\partial l_o} \frac{\theta_{y,t,f}}{\theta_{y,b,f}} - \frac{1}{1+\sigma} \kappa \frac{\partial \lambda_f}{\partial l_o}. \end{aligned}$$

[36] As we have seen in the case of a representative firm, in a framework with demotions, a potential increase in demotions should not fully compensate the increase in the number of older workers in the top job.

From the second equation, we can conclude that the marginal change in the top wage could be lower than that in the bottom wage and possibly even negative. In short, in equilibrium, younger workers hold worse positions within firms' hierarchies, although the overall effect on their mean wages is ex-ante unknown.

The second part of Proposition 3 stems from the assumption that the retention rates of older workers tend to be higher among higher-productivity and higher-paying firms. This assumption can be micro-founded by directly modeling the retirement decisions of older workers. For example, we can assume that, at the beginning of period 0, older workers decide whether to retire or not by comparing their current wage against a disutility of work that is drawn from the same distribution for all older workers in the market. Then, the share of older workers whose wage is higher than their disutility of work is bound to be larger among firms with higher mean wages and a higher productivity shifter $A_f$. Moreover, this assumption is also consistent with prior work that has documented a positive correlation between retention rates, worker compensation, and firm productivity (for example, Bender et al. (2018) and Ruffini (2022)).

In this context, we are assuming that $\rho_f > \rho_{f'}$ for every pair of firms $f$ and $f'$ such that $A_f > A_{f'}$. In other words, $\partial \rho_f / \partial A_f > 0$. What follows is that $\partial l_{o,t,f} / \partial l_o = \rho_f \partial l^{-1}_{o,t,f} / \partial l_o > \rho_{f'} \partial l^{-1}_{o,t,f'} / \partial l_o = \partial l_{o,t,f'} / \partial l_o$, because (i) $\rho_f > \rho_{f'}$, and (ii) $\partial l^{-1}_{o,t,f} / \partial l_o > \partial l^{-1}_{o,t,f'} / \partial l_o$. The change in the number of older workers in the top job of each firm $f$ depends on both (i) the share of the total number of older workers in the market employed by firm $f$, and (ii) the share of the total number of older workers employed by $f$ assigned to the top job $t$. Therefore, the second inequality holds because, if we assume that firms optimized the allocation of older workers in the pre-game period, firms with higher productivity employ a higher share of the total number of older workers in the market. It is also plausible to assume that the same firms have a higher share of older workers slotted in the top job (if the ratio of the worker-productivity parameters in the top and bottom job increases with firm productivity), although it is not necessary to generate the second prediction in Proposition 3.

Finally, the third part of Proposition 3 studies where the younger workers who are precluded from reaching top jobs due to workforce aging find employment. The main takeaway is that, while the decline in the employment of younger workers in top jobs is larger in magnitude within higher-productivity firms, the increase in the employment of younger workers in bottom jobs is not necessarily larger within the same set of firms. In fact, younger workers are more likely to move to firms that experience larger percentage increases in the bottom wage due to workforce aging (thanks to the relative-labor-supply channel).

We can see this point by considering the derivative $\partial \frac{l_{y,b,f'}}{l_{y,b,f}} / \partial l_o$ between any pairs of firms $f$ and $f'$:

$$
\begin{aligned}
\frac{\partial \frac{l_{y,b,f'}}{l_{y,b,f}}}{\partial l_o} &= \frac{\partial}{\partial l_o} \left( \frac{w_{y,j,f'} X_{y,f'}}{w_{y,j,f} X_{y,f}} \right)^{\frac{1}{\sigma}} \\
&= \frac{1}{\sigma} \left( \frac{w_{y,j,f'} X_{y,f'}}{w_{y,j,f} X_{y,f}} \right)^{\frac{1}{\sigma}-1} \frac{\frac{\partial w_{y,b,f'}}{\partial l_o} X_{y,f'} w_{y,j,f} X_{y,f} - \frac{\partial w_{y,b,f}}{\partial l_o} X_{y,f} w_{y,j,f'} X_{y,f'}}{\left( w_{y,j,f} X_{y,f} \right)^2} \\
&= \frac{1}{\sigma} \frac{l_{y,b,f'}}{l_{y,b,f}} \left( \frac{\frac{\partial w_{y,b,f'}}{\partial l_o}}{w_{y,b,f'}} - \frac{\frac{\partial w_{y,b,f}}{\partial l_o}}{w_{y,b,f}} \right) > 0.
\end{aligned}
$$

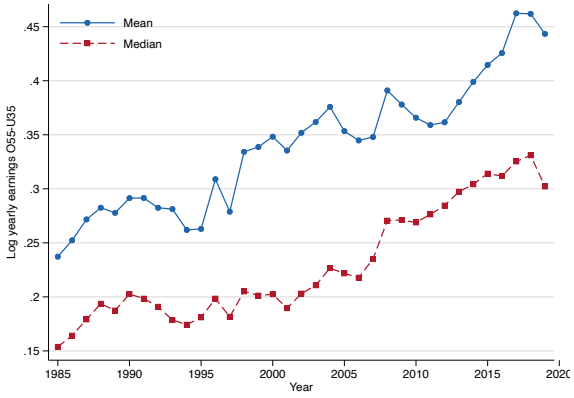
In short, the employment of younger workers in the bottom job increases more in firm $f'$ than in firm $f$ if $\frac{\frac{\partial w_{y,b,f'}}{\partial l_o}}{w_{y,b,f'}} > \frac{\frac{\partial w_{y,b,f}}{\partial l_o}}{w_{y,b,f}}$. Moreover, the differential increase between the two firms is positively corre-

lated with the ratio between the two employment levels in the bottom job at baseline ($l_{y,b,f'}/l_{y,b,f}$). All else equal, lower-productivity firms could experience larger percentage increases in the bottom wage as a result of workforce aging primarily because their bottom wage at baseline is lower.

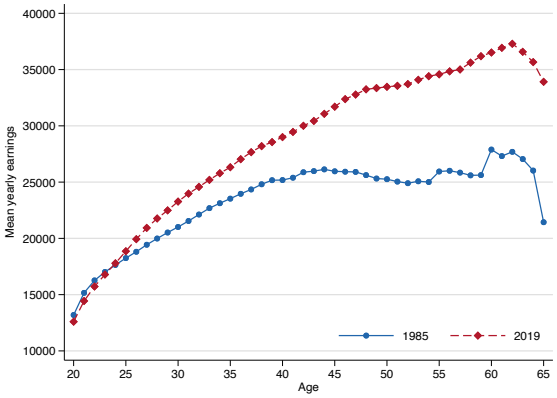
# C Additional Results

## C.1 Figures and Tables

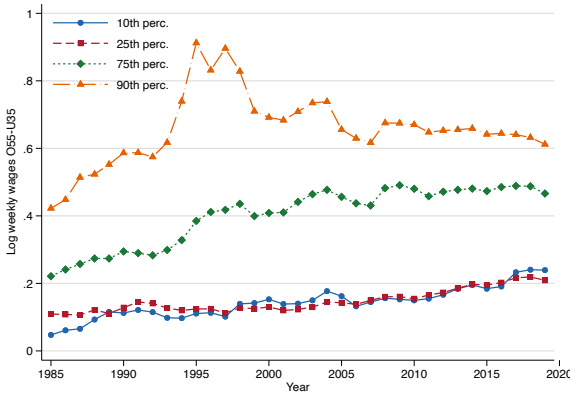
**Figure C1:** Age Pay Gap in Yearly Labor Earnings and at Various Percentiles



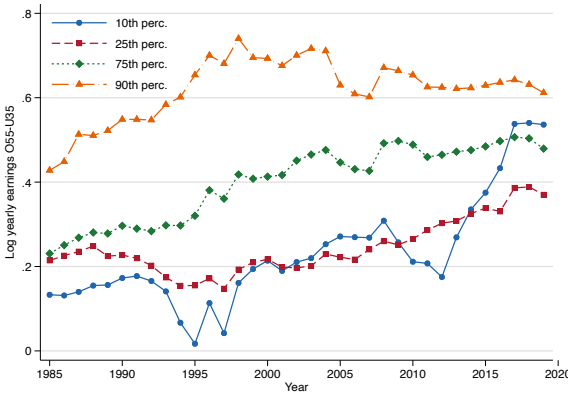

Panel A: Gap in log mean and median yearly earnings




Panel B: Age profiles for mean yearly earnings



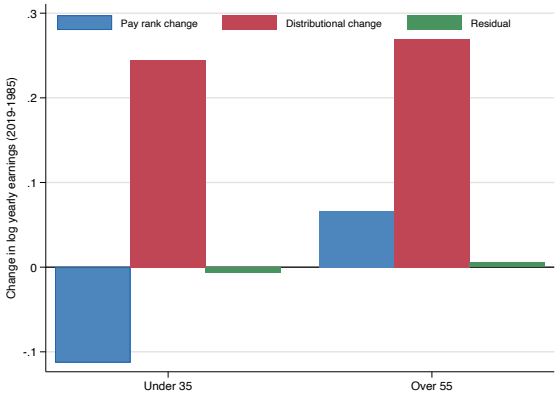

Panel C: Gap at various percentiles (weekly wages)



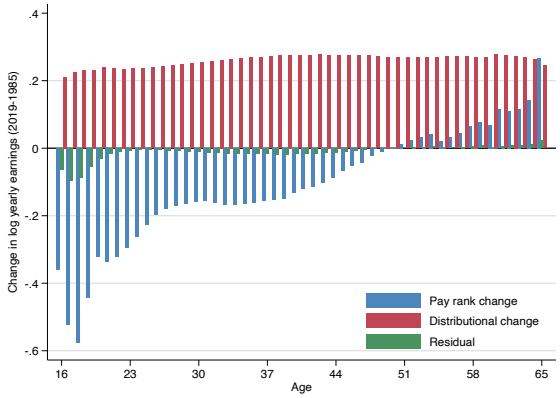

Panel D: Gap at various percentiles (yearly earnings)

*Notes:* Panel A plots the gap between the log yearly earnings of O55 workers and the log yearly earnings of U35 workers from 1985 to 2019 for both mean and median wages. Panel B plots the mean real yearly earnings (not logged) by age in 1985 and 2019. Panels C and D plot the age pay gap (O55 workers - U35 workers) for weekly wages and yearly earnings, respectively, at various percentiles of the wage distribution.
*Sources:* In each year, the data pool information about all workers who were at least 16 years old, had worked at least six months, had earned strictly positive wages, had full-time contracts, and had not retired by December 31. Database: UNIEMENS, Istituto Nazionale della Previdenza Sociale (Italy).

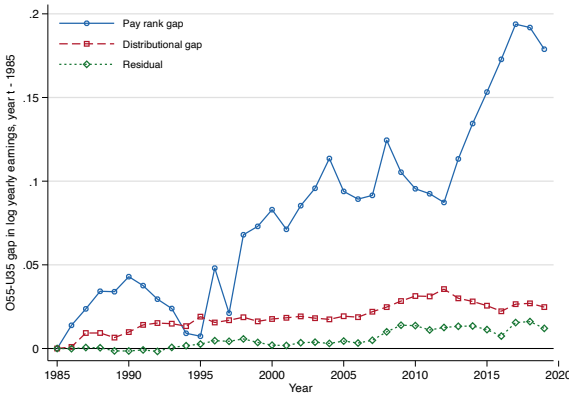
**Figure C2:** The Rank Change in Yearly Earnings




Panel A: U35 and O55 workers, 2019-1985



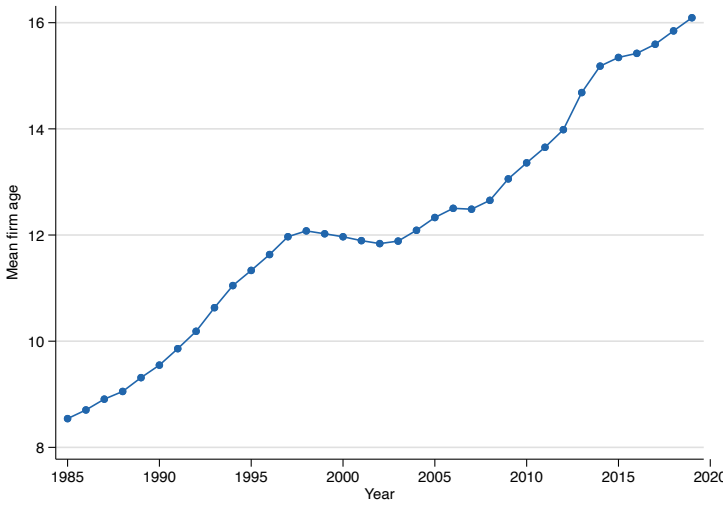

Panel B: All age groups, 2019-1985



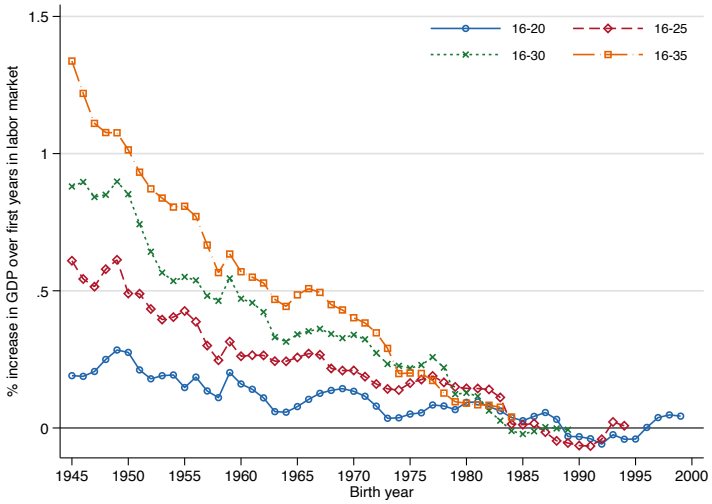

Panel C: O55 workers - U35 workers, $t \in [1986, 2019] - 1985$

*Notes:* Panel A shows the decomposition of the change in the mean log yearly earnings between 1985 and 2019 into the three components of Equation (2). Panel B shows the same decomposition for individual age groups. Panel C shows the same decomposition for the change in the age pay gap between O55 and U35 workers from 1985 to each year $t \in [1986, 2019]$.
*Sources:* In each year, the data pool information about all workers who were at least 16 years old, had worked at least six months, had earned strictly positive wages, had full-time contracts, and had not retired by December 31. Database: UNIEMENS, Istituto Nazionale della Previdenza Sociale (Italy).

**Figure C3:** Firm Aging and GDP Growth



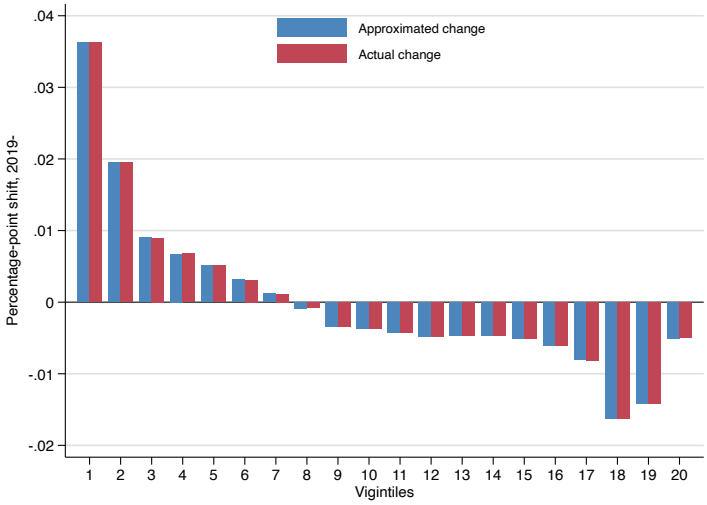

Panel A: Mean firm age



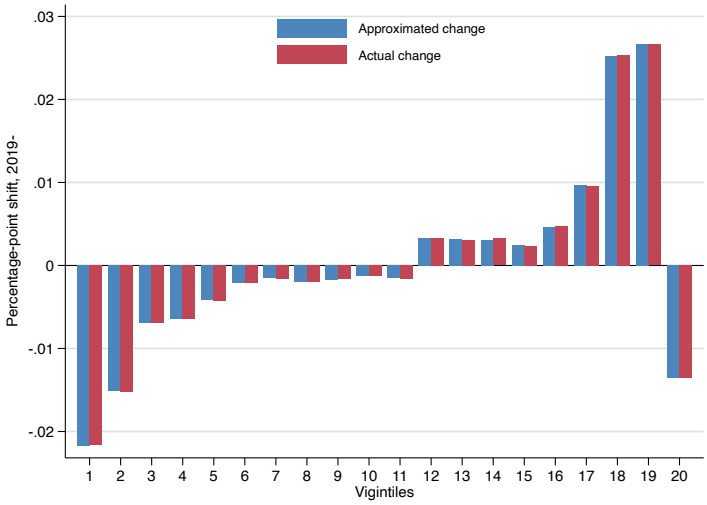

Panel B: GDP growth at labor-market entry

*Notes:* Panel A plots the mean age of firms between 1985 and 2019. Firm age is not right censored at the beginning of the sample, because the foundation year is known even when it predates the start of the Italian Social Security data. Panel B computes the percentage change in GDP (in 2010 USD) over the first years in the labor market for individuals born in different years. For example, the data point for the variable "16-20" and birth year 1945 computes the percentage growth in GDP between 1961 (when individuals born in 1945 were 16 years old) and 1965 (when individuals born in 1945 were 20 years old).
*Sources for Italy:* In each year, the data pool information about all workers who were at least 16 years old, had worked at least six months, had earned strictly positive wages, had full-time contracts, and had not retired by December 31. Database: UNIEMENS, Istituto Nazionale della Previdenza Sociale (INPS). *Sources for GDP data*: World Development Indicators by the World Bank, available online at https://databank.worldbank.org/reports.aspx?source=2&series=NY.GDP.MKTP.CD&country=, last accessed on April 21, 2023.

**Figure C4:** Actual Vs. Approximated Shares



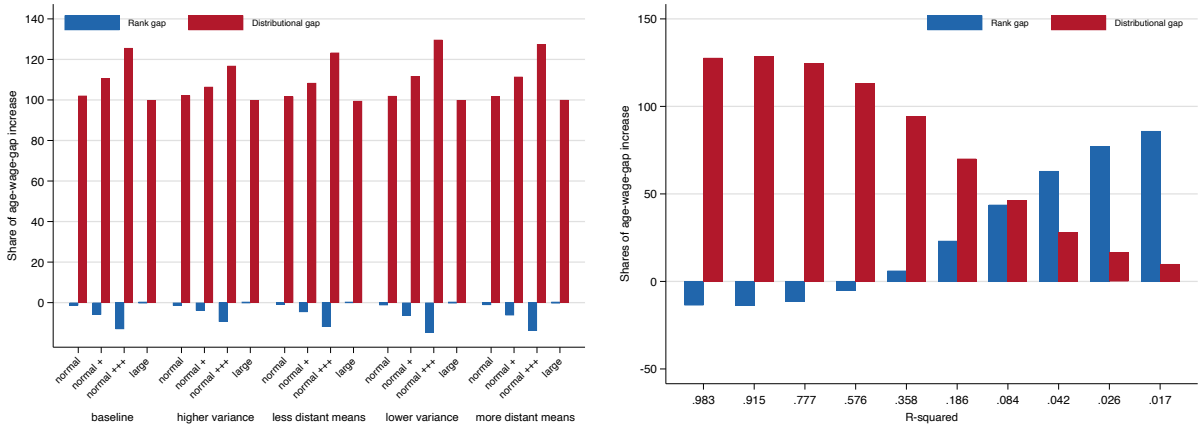

Panel A: U35 workers




Panel B: O55 workers

*Notes:* These graphs show the percentage-point difference in the share of U35 workers (Panel A) or O55 workers (Panel B) in each vigintile of the distribution of weekly wages between 1985 and 2019. "Actual change" plots these differences using the raw distribution of weekly wages. "Approximated change" plots these differences using the distribution that arises from the sorting described in Section 4.3. Specifically, workers are sorted in 100 percentiles (firm groups) based on their firm's average weekly wages. Discrepancies between actual and approximated shares may arise due to the binning of workers in equally sized firm groups. The graphs show that these discrepancies are inconsequential. *Sources:* In each year, the data pool information about all workers who were at least 16 years old, had worked at least six months, had earned strictly positive wages, had full-time contracts, and had not retired by December 31. Database: UNIEMENS, Istituto Nazionale della Previdenza Sociale (Italy).

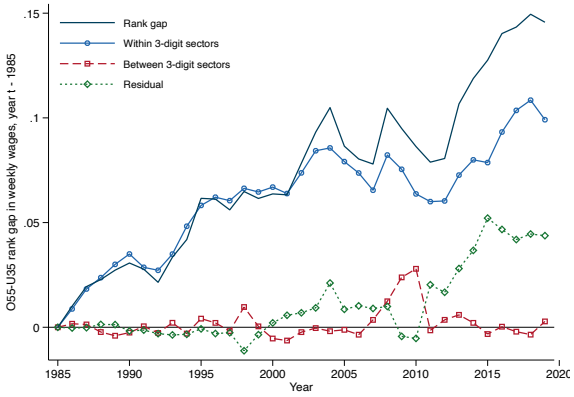
**Figure C5:** Simulating an Increase in Returns to Experience and High-Level Skills



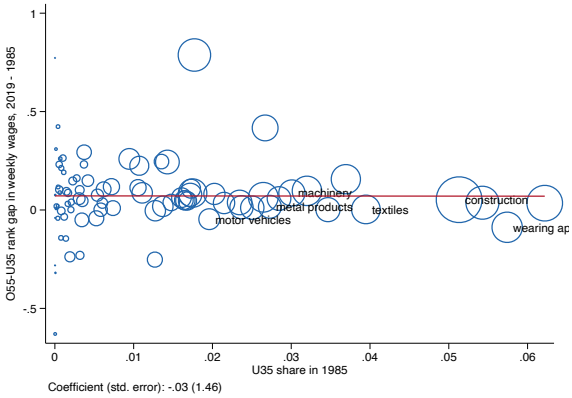

Panel A: $\sigma^2_\varepsilon = 0$ Panel B: $\sigma^2_\varepsilon > 0$

*Notes:* Wage in period $t$ is computed using the following equation: $w^t_{i,a} = \beta_0 + \beta^t_1 x^t_{i,a} + \varepsilon^t_i$. Under the baseline scenario, the variable $x$ is distributed across younger (Y) and older (O) workers as follows: $x^t_{\text{Y}} \sim N(4.9, 0.16)$ and $x^t_{\text{O}} \sim N(5.1, 0.36)$. The share of older workers at $t$ is 9 percent, while $\varepsilon^t_i \sim N(0, \sigma^2_\varepsilon)$. We chose this calibration to match five moments in the first available year of the Italian administrative data: the mean (5.9) and standard deviation (0.4) of the log weekly wages of U35 workers, the mean (6.1) and standard deviation (0.6) of the log weekly wages of O55 workers, and the ratio between O55 workers and U35 workers (0.09). In Panel A, $\sigma^2_\varepsilon = 0$. The graph shows five scenarios and four simulations for each scenario. Under scenario "higher variance," the distributions of $x$ have higher variance: $x^t_{\text{Y}} \sim N(4.9, 0.20)$, $x^t_{\text{O}} \sim N(5.1, 0.42)$ and $x^t_{\text{Y}} \sim N(4.95, 0.16)$. Under scenario "less distant means," the difference in the means of $x$ between younger (Y) and older (O) is smaller: $x^t_{\text{Y}} \sim N(4.95, 0.16)$ and $x^t_{\text{O}} \sim N(5.1, 0.36)$. Under scenario "lower variance," the distributions of $x$ have lower variance: $x^t_{\text{Y}} \sim N(4.9, 0.12)$ and $x^t_{\text{O}} \sim N(5.1, 0.30)$. Under scenario "more distant means," the difference in the means of $x$ is bigger: $x^t_{\text{Y}} \sim N(4.85, 0.16)$ and $x^t_{\text{O}} \sim N(5.1, 0.36)$. For each scenario, Panel A shows four simulations. "Normal" simulates an increase in $\beta^t_1$ from 1 to 1.5. "Normal +" simulates the same increase in $\beta^t_1$ and allows the share of older people to increase to 20 percent. "Normal +++" simulates the same increase in $\beta^t_1$ and allows the share of older people to increase to 35 percent. "Large" simulates an increase in $\beta^t_1$ from 1 to 2.5. For each simulation, Panel A calculates the increase in the age wage gap, and decomposes it using Equation (**??**). In Panel B, $\sigma^2_\varepsilon > 0$. Under the "Baseline" scenario and the "Normal" simulation, Panel B shows the results of the decomposition in Equation (**??**) when the standard deviation $\sigma_\varepsilon$ is allowed to increase from 0.05 to 0.5 in 0.05 increments. In this case, the standard deviations of $x^t_{\text{Y}}$ and $x^t_{\text{O}}$ decrease accordingly, until they reach 0.01. The x-axis shows the $\text{R}^2$ from the regressions of $w^t_{i,a}$ on $x^t_{i,a}$ for different values of $\sigma_\varepsilon$. All simulations were performed on 2,000,000 observations.

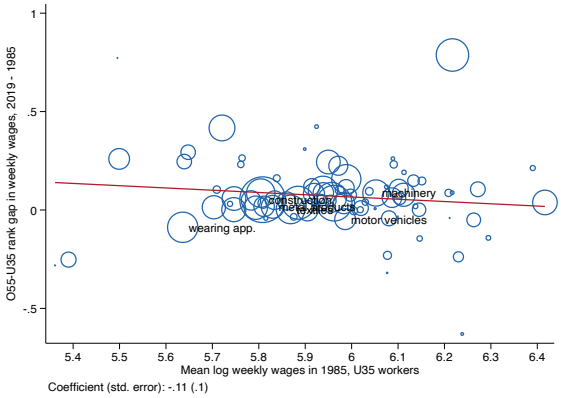
**Figure C6:** Sectoral and Occupational Shifts



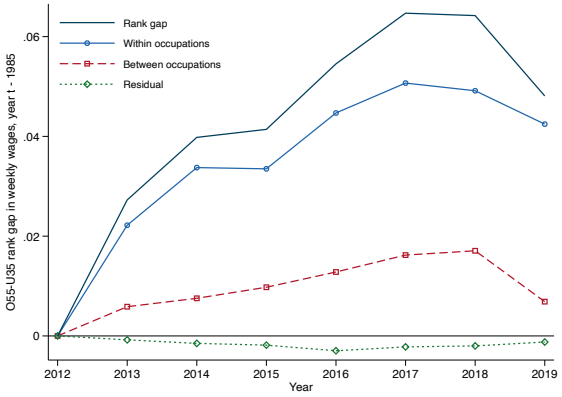

Panel A: Between and within three-digit sectors




Panel B: Rank gap's increase by U35 workers' share in 1985



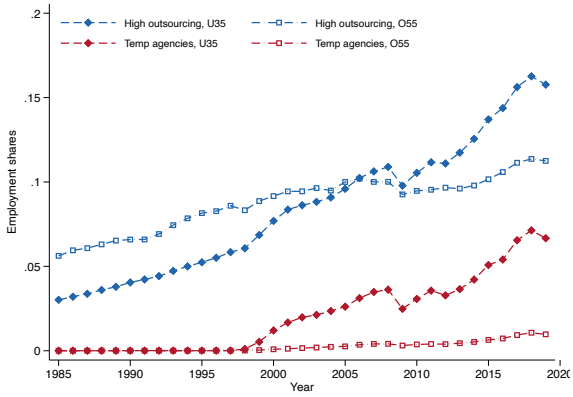

Panel C: Rank gap's increase by U35 workers' mean log weekly wage in 1985



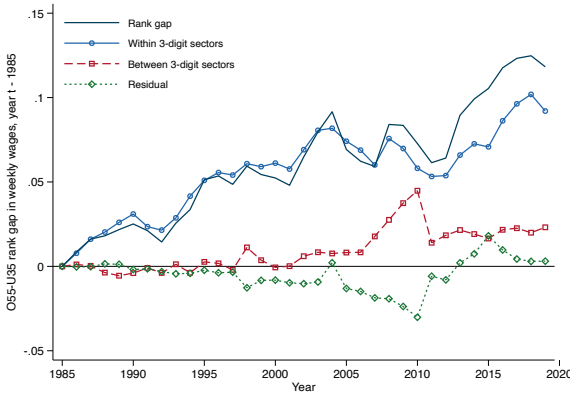

Panel D: Between and within one-digit ISCO-08 occupations

*Notes:* In Panel A, the increase in rank gap in log weekly wages between O55 workers and U35 workers and between year $t$ and 1985 is decomposed between and within three-digit sectors (Equation (**??**)). Panel B plots the increase in the age gap in each two-digit sector against the sector-level share of U35 workers in 1985. Panel C plots the increase in the age gap in each two-digit sector against the sector-level mean log weekly wage of U35 workers in 1985. In Panels B and C, the size of each data point reflects the overall employment share (including both U35 workers and O55 workers) in each sector at baseline. Panel D shows the decomposition of the rank gap's increase between and within one-digit occupations. The ten one-digit occupations follow the categorization prepared by the International Standard Classification of Occupations (ISCO-08). Here, the panel starts in 2012, the first year with occupation data.
*Sources:* In each year, the data pool information about all workers who were at least 16 years old, had worked at least six months, had earned strictly positive wages, had full-time contracts, and had not retired by December 31. Database: UNIEMENS, Istituto Nazionale della Previdenza Sociale (Italy).

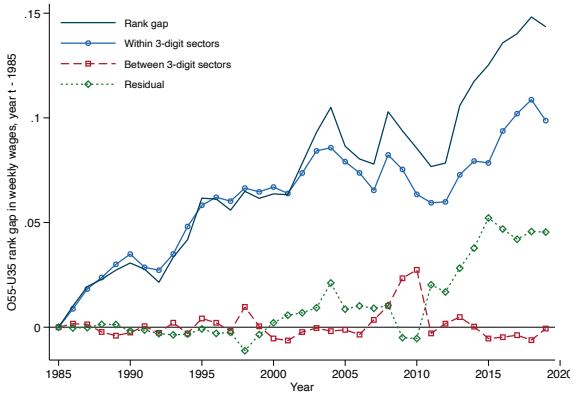
**Figure C7:** Domestic Outsourcing



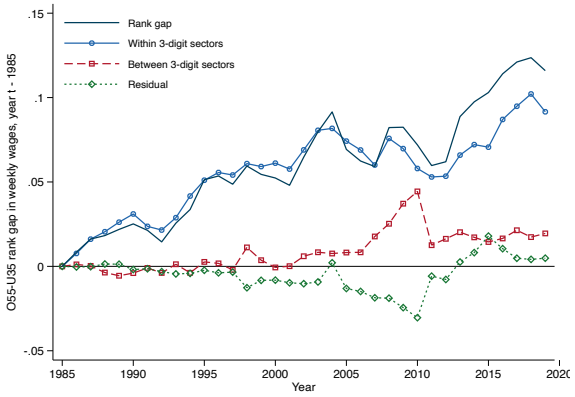

Panel A: Employment shares in high-outsourcing sectors




Panel B: Between and within three-digit sectors, no high-outsourcing sectors




Panel C: Between and within three-digit sectors, no sales of business units




Panel D: Between and within three-digit sectors, no high-outsourcing sectors and sales of business units

*Notes:* Panel A shows the employment shares of U35 and O55 workers in three-digit sectors identified by Goldschmidt and Schmieder (2017) as being highly exposed to domestic outsourcing. "High-outsourcing" sectors are food, cleaning, security, logistics, and temp agencies (Table A-5 in Goldschmidt and Schmieder (2017)). The three-digit (NACE Rev. 2) corresponding codes are: 49.2, 49.4, 50.2, 50.4, 51.2, 52.1, 52.2, 56.2, 78.1, 78.2, 78.3, 80.1, 80.2, 80.3, 81.1, 81.2, 82.1, 82.2, 82.9. "Temp agencies" are sectors 78.1, 78.2, and 78.3. Panel B shows the decomposition of the rank gap's increase between and within three-digit sectors, dropping from the sample all high-outsourcing sectors and temp agencies. Panel C performs the same analysis, dropping all workers employed by firms that have sold at least one business unit (*cessione di ramo d'azienda* in Italian). Panel D drops high-outsourcing sectors, temp agencies, and all workers employed by firms that have sold at least one business unit.

*Sources:* In each year, the data pool information about all workers who were at least 16 years old, had worked at least six months, had earned strictly positive wages, had full-time contracts, and had not retired by December 31. Database: UNIEMENS, Istituto Nazionale della Previdenza Sociale (Italy).

**Table C1:** Age Wage Gap and Workforce Composition

| | Baseline | | Gender | | Nationality | | Contract length | | Education | | Disability | | All | | U35 vs. 56-60 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Δ wage gap (log) | Rank gap (%) | Δ wage gap (log) | Rank gap (%) | Δ wage gap (log) | Rank gap (%) | Δ wage gap (log) | Rank gap (%) | Δ wage gap (log) | Rank gap (%) | Δ wage gap (log) | Rank gap (%) | Δ wage gap (log) | Rank gap (%) | Δ wage gap (log) | Rank gap (%) |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) |
| Panel A: Employer-employee administrative data | | | | | | | | | | | | | | | | |
| Italy (1985-2019) | 0.185 | 78.32 | 0.243 | 79.15 | 0.168 | 79.77 | 0.124 | 81.70 | - | - | - | - | 0.161 | 83.51 | 0.181 | 74.12 |
| Germany (1996-2017) | 0.101 | 55.83 | 0.112 | 64.79 | 0.093 | 58.48 | - | - | 0.137 | 25.59 | - | - | 0.146 | 35.02 | 0.133 | 73.10 |
| Panel B: Survey data from the Luxembourg Income Study (LIS) Database | | | | | | | | | | | | | | | | |
| Australia (1995-2018) | 0.177 | 80.01 | 0.201 | 82.39 | 0.182 | 79.02 | - | - | - | - | - | - | 0.235 | 82.71 | 0.159 | 80.75 |
| Canada (1973-2018) | 0.174 | 77.02 | 0.224 | 77.37 | 0.194 | 78.67 | - | - | 0.191 | 187.68 | - | - | 0.231 | 72.88 | 0.194 | 80.34 |
| Denmark (1987-2016) | 0.185 | 136.71 | 0.195 | 126.48 | 0.175 | 141.67 | - | - | 0.180 | 136.16 | - | - | 0.169 | 127.38 | 0.187 | 137.94 |
| Finland (1987-2016) | 0.214 | 102.73 | 0.200 | 99.74 | - | - | - | - | 0.214 | 100.88 | 0.209 | 86.93 | 0.131 | 99.61 | 0.195 | 103.23 |
| France (2002-2018) | 0.029 | 40.36 | 0.033 | 42.79 | 0.034 | 48.93 | -0.023 | 171.84 | 0.043 | 137.79 | - | - | -0.026 | 5.82 | 0.001 | 30.08 |
| Germany (1994-2018) | 0.084 | 48.40 | 0.117 | 57.88 | 0.077 | 40.25 | -0.028 | 182.60 | 0.113 | 67.15 | 0.101 | 83.07 | 0.058 | 54.72 | 0.129 | 63.89 |
| Greece (1995-2016) | 0.180 | 100.75 | 0.248 | 93.33 | 0.179 | 105.25 | - | - | 0.201 | 100.91 | - | - | 0.177 | 97.43 | 0.190 | 101.76 |
| Israel (1979-2018) | 0.412 | 53.53 | 0.451 | 55.72 | - | - | - | - | 0.351 | 56.40 | - | - | 0.371 | 59.13 | 0.574 | 53.52 |
| Netherlands (1983-2018) | 0.226 | 7.69 | 0.277 | 24.17 | - | - | - | - | 0.312 | 25.84 | - | - | 0.221 | -53.53 | 0.237 | 13.21 |
| Norway (1986-2016) | 0.159 | 77.78 | 0.178 | 64.62 | - | - | - | - | 0.178 | 76.84 | 0.139 | 76.45 | 0.166 | 57.48 | 0.123 | 68.95 |
| Spain (1993-2018) | 0.509 | 60.99 | 0.535 | 62.87 | 0.447 | 62.20 | - | - | 0.506 | 56.85 | 0.498 | 66.88 | 0.282 | 57.72 | 0.467 | 58.24 |
| Switzerland (1982-2018) | 0.481 | 49.61 | 0.472 | 53.87 | 0.442 | 53.61 | - | - | - | - | - | - | 0.304 | 54.68 | 0.355 | 28.05 |
| United Kingdom (1979-2018) | 0.042 | 15.24 | 0.093 | 51.95 | - | - | - | - | - | - | 0.046 | 98.83 | 0.142 | 51.95 | 0.035 | 10.65 |
| United States (1979-2018) | 0.136 | 89.00 | 0.163 | 78.08 | 0.112 | 94.02 | - | - | 0.111 | 100.39 | - | - | 0.127 | 82.41 | 0.098 | 88.36 |

*Notes:* "Gender" regresses log wages on a male dummy and computes the age wage gap using the residuals from these regressions. "Nationality" uses a dummy for nonimmigrant workers as a regressor (a dummy for white workers in the United States to control for race, instead). "Contract length" controls for temporary contracts. "Education" controls for college education. "Disability" controls for disability status. "All" simultaneously controls for all the worker characteristics available in each country. "U35 vs. 56-60" computes the age wage gap between male workers aged between 56 and 60 and U35 workers.
*Sources for Italy:* Database UNIEMENS, Istituto Nazionale della Previdenza Sociale (INPS). *Sources for Germany:* LIAB Linked Employer-Employee Dataset provided by the Institute for Employment Research. *Sources for survey data:* Luxembourg Income Study (LIS) Database, which we last accessed on 04/14/2023 at https://www.lisdatacenter.org/.

**Table C2:** Men's Minimum Pensionable Age At Baseline

| | Men's minimum pensionable age | Data source |
|---|---|---|
| | (1) | (2) |
| Australia (1995-2018) | 65 years | Table 1.1, OECD's Pension at a Glance 2011, http://dx.doi.org/10.1787/888932372089 |
| Canada (1973-2018) | 68 years | Table 1.1, OECD's Pension at a Glance 2011, http://dx.doi.org/10.1787/888932372089 |
| Denmark (1987-2016) | 67 years | Table 1.1, OECD's Pension at a Glance 2011, http://dx.doi.org/10.1787/888932372089 |
| Finland (1987-2016) | 65 years | Table 1.1, OECD's Pension at a Glance 2011, http://dx.doi.org/10.1787/888932372089 |
| France (2002-2018) | 60 years | Table 1.1, OECD's Pension at a Glance 2011, http://dx.doi.org/10.1787/888932372089 |
| Germany (1994-2018) | 63 years | Table 1.1, OECD's Pension at a Glance 2011, http://dx.doi.org/10.1787/888932372089 |
| Greece (1995-2016) | 57 years | Table 1.1, OECD's Pension at a Glance 2011, http://dx.doi.org/10.1787/888932372089 |
| Israel (1979-2018) | 65 years | https://www.oecd.org/els/public-pensions/PAG2013-profile-Israel.pdf |
| Italy (1985-2019) | 55 years | Table 1.1, OECD's Pension at a Glance 2011, http://dx.doi.org/10.1787/888932372089 |
| Netherlands (1983-2018) | 65 years | Table 1.1, OECD's Pension at a Glance 2011, http://dx.doi.org/10.1787/888932372089 |
| Norway (1986-2016) | 67 years | Table 1.1, OECD's Pension at a Glance 2011, http://dx.doi.org/10.1787/888932372089 |
| Spain (1993-2018) | 65 years | Table 1.1, OECD's Pension at a Glance 2011, http://dx.doi.org/10.1787/888932372089 |
| Switzerland (1982-2018) | 65 years | Table 1.1, OECD's Pension at a Glance 2011, http://dx.doi.org/10.1787/888932372089 |
| United Kingdom (1979-2018) | 65 years | Table 1.1, OECD's Pension at a Glance 2011, http://dx.doi.org/10.1787/888932372089 |
| United States (1979-2018) | 65 years | Table 1.1, OECD's Pension at a Glance 2011, http://dx.doi.org/10.1787/888932372089 |

*Notes:* For each country, the table shows men's minimum pensionable age in the first available year of data. The main source is Table 1.1. from OECD's Pension at a Glance 2011, available online at http://dx.doi.org/10.1787/888932372089 (last accessed on May 11, 2023). Pensionable age is defined "as the age at which people can first draw full benefits (that is, without actuarial reduction for early retirement). (p.20)"

## C.2 Derivation of Equation (2)

The change in mean log wage for age group $a$ between years $t$ and $t'$ can be written as follows:

$$\Delta w_a^{t,t'} = \underbrace{\sum_v \left(s_{a,v,t'} - s_{a,v,t}\right) \bar{w}_{v,t}}_{\text{Pay rank change}} + \underbrace{\sum_v s_{a,v,t} \left(\bar{w}_{v,t'} - \bar{w}_{v,t}\right)}_{\text{Distributional change}} + \underbrace{\sum_v \left(s_{a,v,t'} - s_{a,v,t}\right) \left(\bar{w}_{v,t'} - \bar{w}_{v,t}\right)}_{\text{Residual}}. \tag{C.1}$$

In this equation, $s_{a,v,t}$ is the share of workers in age group $a$, vigintile $v$ of the distribution of wages, and year $t$, while $\bar{w}_{v,t}$ is the mean log wage in vigintile $v$ and year $t$. This decomposition can be obtained as follows:

$$\begin{aligned}
\Delta w_a^{t,t'} &= \sum_v s_{a,v,t'} \bar{w}_{v,t'} - \sum_v s_{a,v,t} \bar{w}_{v,t} \\
&= \sum_v s_{a,v,t'} \bar{w}_{v,t'} - \sum_v s_{a,v,t} \bar{w}_{v,t} + \sum_v s_{a,v,t'} \bar{w}_{v,t} - \sum_v s_{a,v,t'} \bar{w}_{v,t} \\
&= \sum_v \left(s_{a,v,t'} - s_{a,v,t}\right) \bar{w}_{v,t} + \sum_v s_{a,v,t'} \left(\bar{w}_{v,t'} - \bar{w}_{v,t}\right) \\
&= \sum_v \left(s_{a,v,t'} - s_{a,v,t}\right) \bar{w}_{v,t} + \sum_v s_{a,v,t'} \left(\bar{w}_{v,t'} - \bar{w}_{v,t}\right) \\
&\quad + \sum_v s_{a,v,t} \left(\bar{w}_{v,t'} - \bar{w}_{v,t}\right) - \sum_v s_{a,v,t} \left(\bar{w}_{v,t'} - \bar{w}_{v,t}\right) \\
&= \underbrace{\sum_v \left(s_{a,v,t'} - s_{a,v,t}\right) \bar{w}_{v,t}}_{\text{Pay rank change}} + \underbrace{\sum_v s_{a,v,t} \left(\bar{w}_{v,t'} - \bar{w}_{v,t}\right)}_{\text{Distributional change}} \\
&\quad + \underbrace{\sum_v \left(s_{a,v,t'} - s_{a,v,t}\right) \left(\bar{w}_{v,t'} - \bar{w}_{v,t}\right)}_{\text{Residual}}.
\end{aligned}$$

The gap in the average log wage between U35 workers and O55 workers, as well as between years $t$ and $t'$, can be written as follows:

$$\Delta w_{O55}^{t,t'} - \Delta w_{U35}^{t,t'} = \underbrace{\sum_v \Delta s_{O55-U35,v,t'-t} \bar{w}_{v,t}}_{\text{Pay rank gap}} + \underbrace{\sum_v \left(s_{O55,v,t} - s_{U35,v,t}\right) \left(\bar{w}_{v,t'} - \bar{w}_{v,t}\right)}_{\text{Distributional gap}} + \underbrace{\sum_v \Delta s_{O55-U35,v,t'-t} \left(\bar{w}_{v,t'} - \bar{w}_{v,t}\right)}_{\text{Residual}}. \tag{C.2}$$

In this equation, $\Delta s_{O55-U35,v,t'-t} = \left(s_{O55,v,t'} - s_{O55,v,t}\right) - \left(s_{U35,v,t'} - s_{U35,v,t}\right)$ is the double difference in the share of workers in vigintile $v$ (i) between O55 workers and U35 workers and (ii) between

years $t$ and $t'$. This decomposition can be obtained as follows:

$$\begin{aligned}
\Delta w_{O55}^{t,t'} - \Delta w_{U35}^{t,t'} &= \sum_v \left(s_{O55,v,t'} - s_{O55,v,t}\right) \bar{w}_{v,t} + \sum_v \left(s_{O55,v,t'} - s_{O55,v,t}\right) \left(\bar{w}_{v,t'} - \bar{w}_{v,t}\right) \\
&\quad + \sum_v s_{O55,v,t} \left(\bar{w}_{v,t'} - \bar{w}_{v,t}\right) - \sum_v \left(s_{U35,v,t'} - s_{U35,v,t}\right) \bar{w}_{v,t} \\
&\quad - \sum_v \left(s_{U35,v,t'} - s_{U35,v,t}\right) \left(\bar{w}_{v,t'} - \bar{w}_{v,t}\right) - \sum_v s_{U35,v,t} \left(\bar{w}_{v,t'} - \bar{w}_{v,t}\right) \\
&= \sum_v \left(\left(s_{O55,v,t'} - s_{O55,v,t}\right) - \left(s_{U35,v,t'} - s_{U35,v,t}\right)\right) \bar{w}_{v,t} \\
&\quad + \sum_v \left(\left(s_{O55,v,t'} - s_{O55,v,t}\right) - \left(s_{U35,v,t'} - s_{U35,v,t}\right)\right) \left(\bar{w}_{v,t'} - \bar{w}_{v,t}\right) \\
&\quad + \sum_v \left(s_{O55,v,t} - s_{U35,v,t}\right) \left(\bar{w}_{v,t'} - \bar{w}_{v,t}\right) \\
&= \underbrace{\sum_v \Delta s_{O55-U35,v,t'-t} \bar{w}_{v,t}}_{\text{Pay rank gap}} + \underbrace{\sum_v \left(s_{O55,v,t} - s_{U35,v,t}\right) \left(\bar{w}_{v,t'} - \bar{w}_{v,t}\right)}_{\text{Distributional gap}} \\
&\quad + \underbrace{\sum_v \Delta s_{O55-U35,v,t'-t} \left(\bar{w}_{v,t'} - \bar{w}_{v,t}\right)}_{\text{Residual}}.
\end{aligned}$$

## C.3 Equation (3)

The exact formula of the decomposition of the rank change can be written as follows:

$$\begin{aligned}
\underbrace{\sum_v \left(s_{U35,v,t'} - s_{U35,v,t}\right) \bar{w}_{v,t}}_{\text{Rank change}} &= \underbrace{\sum_{e \in [0,18]} s_{e,t'} \cdot \sum_v \left[s_{e,t',v}^{LME} \cdot \bar{w}_{v,t}\right]}_{\text{Change in entry rank—part 1}} \\
&\quad - \underbrace{\sum_{e \in [0,18]} s_{e,t} \cdot \sum_v \left[s_{e,t,v}^{LME} \cdot \bar{w}_{v,t}\right]}_{\text{Change in entry rank—part 2}} \\
&\quad + \underbrace{\sum_{e \in [0,18]} s_{e,t'} \cdot \sum_v \left[\left(s_{e,t',v} - s_{e,t',v}^{LME}\right) \cdot \bar{w}_{v,t}\right]}_{\text{Change in rank growth—part 1}} \\
&\quad - \underbrace{\sum_{e \in [0,18]} s_{e,t} \cdot \sum_v \left[\left(s_{e,t,v} - s_{e,t,v}^{LME}\right) \cdot \bar{w}_{v,t}\right]}_{\text{Change in rank growth—part 2}}.
\end{aligned} \tag{C.3}$$

There is one key difference between Equation (C.3) and Equation (3) in Section 4.1.3. In the full decomposition in Equation (C.3), the experience composition of U35 workers is allowed to change from year $t$ ($s_{e,t}$) to year $t'$ ($s_{e,t'}$). Therefore, the two components of the decomposition can confound two types of changes: (i) variation in entry rank and rank growth and (ii) variation in the experience distribution of U35 workers. For example, the change in entry rank can stem from the fact that the wage distribution at labor-market entry of workers under 35 in year $t'$ and year $t'$ was different. Or,

it can stem from the fact that U35 workers became either more or less experienced between $t$ and $t'$.

In the main draft, we isolate the first channel. Therefore, we fix the experience distribution either at baseline in year $t$ (1995 for U35 workers and 1990 for U30 workers) or in 2019. This assumption allows us to rewrite Equation (C.3) as Equation (3) in Section 4.1.3.

## C.4 Numerical Framework

Consider a simple wage function: $w_{i,a}^t = \beta_0 + \beta_1^t x_{i,a}^t + \varepsilon_i^t$. Here, $w_{i,a}^t$ denotes the wage of worker $i$ in age group $a \in \{\text{Younger}, \text{Older}\}$ in period $t$, $x_{i,a}^t$ represents the quantity of wage-enhancing factor $x$ possessed by worker $i$ in period $t$, $\beta_1^t$ is the unit price of factor $x$ in period $t$, and $\varepsilon_i^t$ refers to other characteristics correlated with wages. The variable $x$ represents any worker characteristic associated with higher wages, such as experience, skills, education, job level, and other features of the labor contracts. We assume that older workers posses, on average, a higher quantity of $x$, resulting in a higher mean wage for older workers at baseline—a fact corroborated by all available data sources. In contrast, variable $\varepsilon_i^t$ is equally distributed across both worker categories.

To simulate an increase in returns to experience or higher-level skills, we raise the price of the wage-enhancing factor $x$. Given that older workers possess, on average, a larger quantity of $x$, its price hike amplifies the age wage gap. We then utilize Equation (**??**) to decompose this increase into a larger rank gap and a larger distributional gap.

In the baseline scenario, we calibrate the wage equation to match five moments from the Italian administrative data in 1985: mean (5.9) and standard deviation (0.4) of log weekly wages of U35 workers, mean (6.1) and standard deviation (0.6) of log weekly wages of O55 workers, and the O55 to U35 workers ratio (0.09). In the wage function, we set $\beta_0 = 1$, $\beta_1^t = 1$, $x_{\text{Y}}^t \sim N(4.9, 0.16)$ for younger workers, $x_{\text{O}}^t \sim N(5.1, 0.36)$ for older workers, and $\varepsilon_i^t \sim N(0, \sigma_\varepsilon^2)$. The variable $\varepsilon_i^t$ has always mean 0, while its variance changes across different scenarios.

In the case of $\sigma_\varepsilon^2 = 0$, $x$ is the sole determinant of individual wages. When its unit price $\beta_1$ increases from 1 in period $t$ to 1.5 in period $t'$, the age wage gap expands by 0.09 log points, a shift entirely attributable to a larger distributional gap (Figure C5, Panel A). This finding holds if we increase the share of older workers in period $t'$ to either 20 percent or 35 percent (matching the 2019 O55 to U35 workers ratio in Italy), and if $\beta_1$ rises to 2.5, instead of 1.5. Moreover, the distributional gap accounts for at least 99 percent of the age wage gap's widening under alternative assumptions for the distribution of $x$.

When $\sigma_\varepsilon^2 > 0$, differences in $x$ account for a smaller share of wage variation (Figure C5, Panel B). In practice, all else equal, the wage distributions of younger and older workers overlap more as the standard deviation of $\varepsilon_i^t$ grows. Following a price increase of $x$ from 1 to 1.5, the distributional gap's contribution declines significantly with $\sigma_\varepsilon$. Specifically, the distributional gap accounts for 128 percent of the age gap's expansion if the standard deviation $\sigma_\varepsilon$ equals 0.05 ($R^2 = 0.983$), 94 percent if $\sigma_\varepsilon = 0.25$ ($R^2 = 0.358$), and 10 percent if $\sigma_\varepsilon = 0.5$ ($R^2 = 0.017$).

The key insight from this exercise is that the mechanism through which an increased price of $x$ expands the age wage gap hinges on the role of $x$ in explaining wage differences between younger and older workers. When the $R^2$ between $x$ and wages is larger (lower values of $\sigma_\varepsilon$), the wage distributions of younger and older workers overlap less. In this case, a rise in $x$'s price pushes many high-earning older workers further ahead of younger workers, primarily widening the age wage gap by extending the wage distribution's right tail. Conversely, when the $R^2$ between $x$ and wages is smaller (higher values of $\sigma_\varepsilon$), the wage distributions of younger and older workers overlap more. In this case, a price increase of $x$ is more likely to propel older workers past younger ones in the wage distribution, thereby expanding the rank gap.