

Aging and the Productivity Puzzle

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Abstract

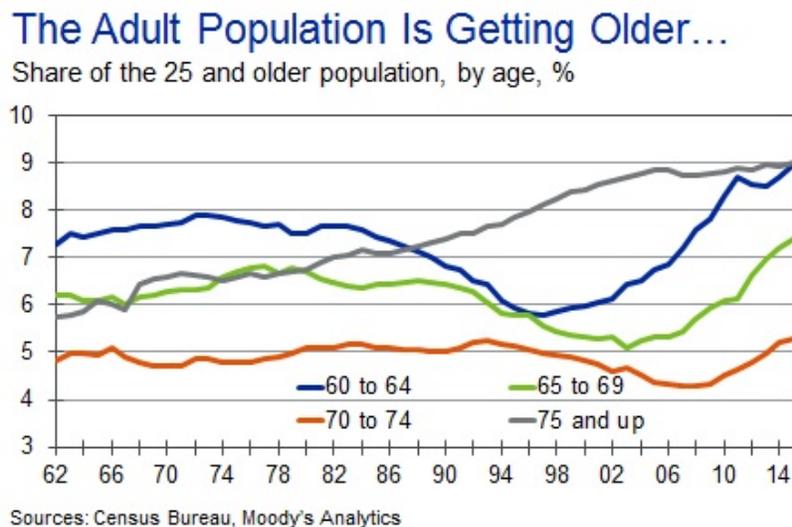
Research on the effect of an aging population on economic growth has tended to focus on labor force participation and the dependency ratio, and the limited work that has examined the effect of aging on productivity remains inconclusive. This analysis contributes to the aging and productivity literature and finds a negative effect of aging on productivity using both state-industry aggregate data and matched employer-employee microdata. The aggregate data show a clear relationship between an older workforce and lower productivity at the state-industry level, in both cross-section and panel models. The results are confirmed using employer-employee linked data from private sector human resource company ADP that show having older coworkers reduces an individual's wages. Robustness tests include ZIP-3 fixed effects and firm fixed effects for a sample of large nationwide firms. The results suggest that between a quarter and full percentage point of the slowing in productivity growth in recent years may be due to aging, an effect that is likely to persist for the next decade.

JEL Codes:

Keywords:

I. Introduction

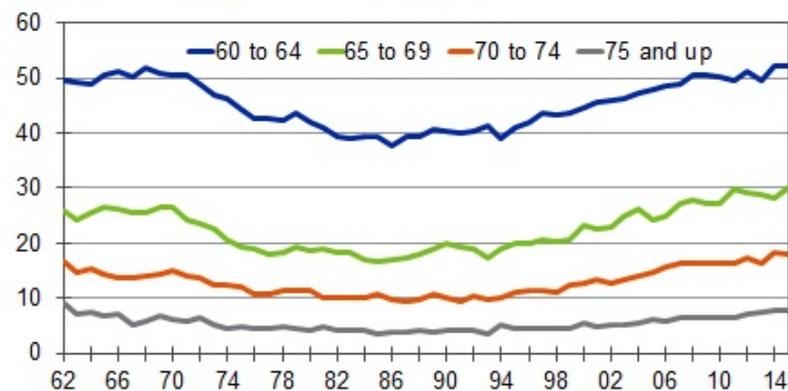
The workforce has aged significantly over the past decade. Two main factors are driving this. Most important is demographics. The baby boom generation, which includes anyone born from 1946 to 1964, is larger than both the generation that came before it and the one after it. As a result, as baby boomers age, so too does the working-age population. Most notably, starting about a decade ago baby boomers began becoming senior citizens, and as a result senior citizens now make up an increasingly large share of the adult population.



Also behind the aging workforce are increasing lifespans and the lack of retirement savings, which are keeping older people in the workforce at greater rates than in the past. This is true for younger seniors as well as older ones.

...And Working More...

Employment-to-population ratio, by age, %

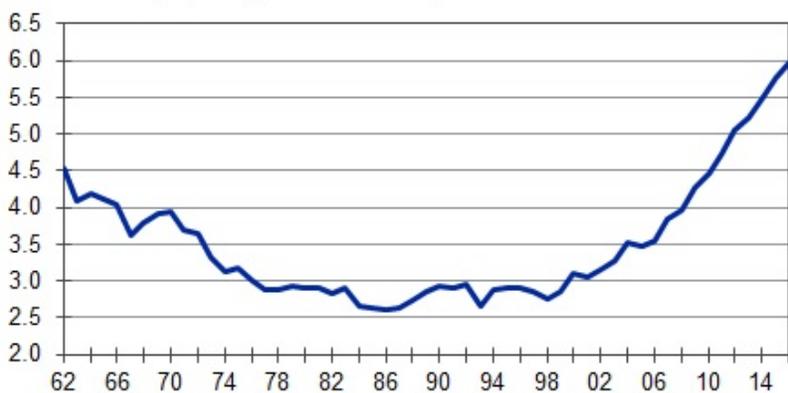


Sources: BLS, Moody's Analytics

The combined effect of an older population and people working more later in life is that the senior share of the workforce has increased significantly, doubling from 3% to 6% in the last 15 years to the highest level on record.

...Leading to an Older Overall Workforce

Share of employed age 65 and older, %



Sources: BLS, Moody's Analytics

The graying of the workforce has occurred alongside declining productivity, raising questions about whether aging is partly responsible for some of the recent slowdown in productivity. However, aside from timing, the theoretical motivation for this connection is not obvious. Past work has been vague or agnostic about the mechanism through which an aging

workforce might affect productivity.¹ A direct effect of aging on a worker’s own productivity is not supported by lifecycle wage data, where the lack of a sharp dropoff in pay for older workers suggests marginal productivity does not drop off either. As a result, it is more plausible that any observed relationship between aging and productivity is due to negative productivity spillovers rather than composition effects of an aging workforce.

One plausible mechanism for productivity spillovers is that an older workforce may slow the adoption of productivity-enhancing technologies that require learning on the part of workers. The benefits from such learning will likely be lowest for older workers, due to shorter remaining careers that provide less time to recoup the upfront costs. The costs may also be higher if older workers have a harder time learning new skills. If firms reap the benefits and pay the costs of the training, it may therefore be profit-maximizing to forgo adopting new technologies. Alternatively, if workers bear some of the costs or benefits, they may block technology adoption via x-inefficiency.

However, the relationship between aging and productivity is not necessarily negative. Acemoglu and Restrepo (2017) provide an intuitive explanation for why an aging population would increase productivity: Scarcity of younger and middle age workers drives adoption of new automation technologies that increase productivity. Alternatively, older workers may generate firm-specific human capital that is not easily replaced by the firm. Using data on 34,000 deaths at German firms, Jäger (2016) shows that, consistent with economist Gary Becker’s notion of firm-specific human capital, the deaths of high-skilled or managerial workers have negative effects on coworker wages.

¹Maestas et al. (2016) provide a model of economic output where human capital productivity of the labor force depends on the age distribution of the workforce, however they provide little intuition or detail about why this might be. Feyrer (2007) discusses the possibility of human capital spillovers due to experience, however “is agnostic as to the mechanisms through which demographic change and productivity are related.”

Overall, the effect of an aging workforce on productivity is theoretically ambiguous, and thus far empirical research has been mixed as well. Maestas et al. (2016) look across U.S. states and find that an increase in the share of the population age 60 and older slows productivity growth significantly. Feyrer (2007) finds that the age distribution of the workforce affects growth in cross-country panel models, but his results suggest positive effects of the 40 to 50 age group rather than negative effects of older workers. Acemoglu and Restrepo (2017) look at more recent cross-country data and find that countries with more aging have higher productivity.

The mixed results and theoretical ambiguity suggest more research is needed. This analysis contributes to the literature by first showing a clear relationship between aggregate aging and productivity in cross-sections of state-industry data for the U.S. To do this, annual Quarterly Workforce Indicators data on the age of the workforce for state-industry pairs is matched to Bureau of Economic Analysis data on productivity. After removing industry and state fixed effects, which control for U.S.-level changes in industry productivity and state-level changes such as a growing dependency ratio, there is a clear relationship between an older workforce and lower productivity. The results are confirmed in cross-sectional and panel regressions on five-year changes from 2005 to 2015, with an elasticity of productivity to the age 65 and older share of workers between 4.0 and 10.8. The aggregate data are suggestive but remain open to reverse causality and a variety of omitted variables.

The results are then confirmed in a more rigorous analysis using matched employer-employee data from ADP, a private sector payroll processor. These data measure within-firm spillover effects directly, ruling out composition effects alone. Separate regressions for each age group confirm that having older workers causes negative spillovers for workers of all ages.

In addition, the ADP data allow for local geographic controls that rule out omitted variables at the three-digit ZIP code level. As a further robustness test, a sample of large national firms with employees located throughout the country is examined, which allows the inclusion of fixed effects to rule out firm-level omitted variables. The consistent results across models, datasets and robustness tests suggest that older workers are causing lower productivity. Simulations from these coefficients suggest that the aging of the workforce can explain between 0.3 and 1.2 percentage points of the slowdown in per annum productivity growth over the last 15 years. Forecasts of population aging suggest that these effects will not dissipate until more than a decade from now.

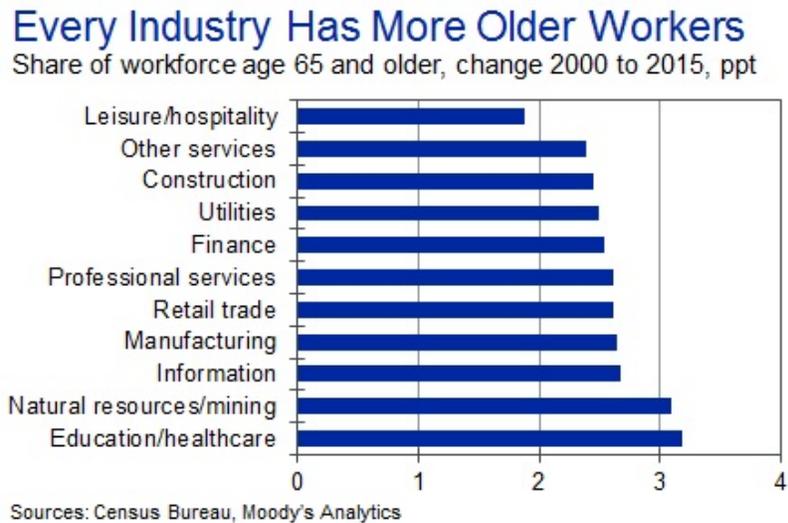
II. State-Industry Models

Given the theoretical indeterminacy of the relationship between aging and productivity, it is worth examining whether aging and low productivity appear correlated in aggregate at the state-industry level. The age distribution of workers by industry and state is available from the Census Bureau's Quarterly Workforce Indicators (QWI), which provide detailed data on matched worker and firm characteristics.² These data reveal that the aging of the workforce is a broad-based phenomenon and has not affected just some industries and states.

From 2000 to 2015, every industry on average has seen an increase in the share of workers age 65 and older, and so has every state. Out of 462 state-industry pairs for which there are data, all but one saw an increase in the senior share of the workforce from 2000 to 2015. The

²The QWI comes from the Census Longitudinal Employer-Household Dynamics data, which are microdata that link employers and employees and cover 95% of private sector employment. The data are available for most states starting in the early 2000s, with the first quarter of data availability varying by state. Industries are categorized by NAICS code.

more complete sample available from 2005 to 2015 shows that 537 out of 538 state-industry pairs saw an increase.³ That almost every industry and state are aging suggests that neither industry-specific nor state-specific factors are driving the entirety of the phenomenon. If only northeastern states or only services industries were aging, it would make cross-sectional or panel analysis more difficult.



Annual state-industry QWI data are matched to Bureau of Economic Analysis data on state-level productivity by industry. Overall, the matched data cover 50 states and Washington DC and 11 industry aggregations. States varied in when they began participating in the QWI, creating a staggered start period with 33% of the 561 state-industry observations⁴ available with QWI data in 1995, 82% in 2000, and 98% or higher for 2005 through 2015.⁵

³The lone decline in both time periods was natural resources and mining in North Dakota, where the senior share of the workforce fell from 3.4% to 2.9% from 2000 to 2015.

⁴561 possible observations are equal to 11 industries x 50 states and DC.

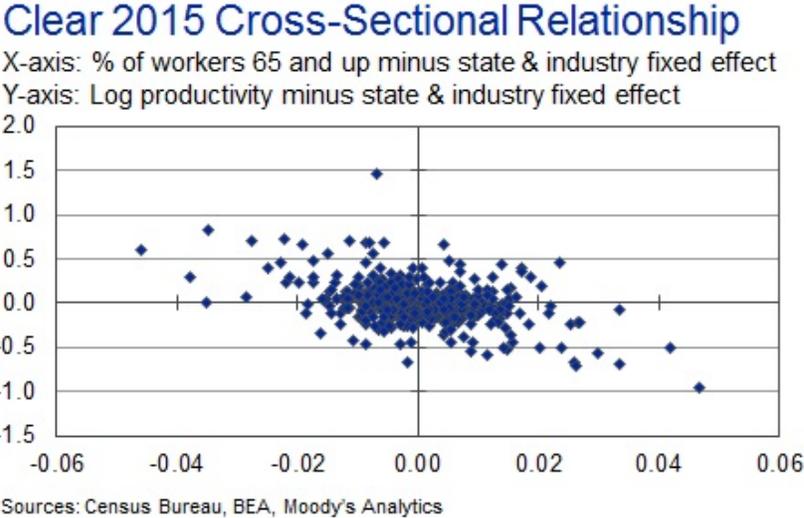
⁵Complete QWI data for Wyoming are available only through 2014, leaving 549 observations in 2015. Productivity and QWI data for natural resources and mining in Washington DC end in 2005, and QWI data for Massachusetts are available only beginning in 2010.

1. The Cross-Sectional Relationship

Perhaps surprisingly, the relationship between aging and productivity is clearly visible in simple cross-section comparisons that ignore changes over time and more complicated panel econometrics. First, both productivity and the share of workers age 65 for every state-industry pair in the year 2015 were regressed on state and industry fixed effects. For outcome variable Y in industry i , state j , time t , the following residual is estimated using the constant, α , and industry and state fixed effects, α_i and α_j :

$$\epsilon_{ijt} = Y_{ijt} - \alpha - \alpha_i - \alpha_j \tag{1}$$

This removes the variation in productivity that is due to effects common to all industries or to all states. The resulting residuals have a clear relationship when plotted against each other, with a higher senior share of workers associated with lower productivity at a correlation of -0.41. The results are similar for 2010 and 2005, with correlation coefficients of exactly -0.41 in these years as well.



Cross-sectional regressions for 2000, 2005, 2010 and 2015 confirm that the relationship between aging and the workforce is statistically significant. Despite the sample changing each year due to the staggered start period for each state, the coefficient is consistent across cross-sections, ranging from -9.28 in 2015 to -10.84 in 2005.

A stacked first difference model from 2005 to 2015 shows that changes in productivity are statistically significantly related to changes in the senior share. This result is robust to the inclusion of state-industry pair job growth. While the coefficient is smaller than the cross-section, it is of a similar magnitude. These results suggest a 1-percentage point increase in the senior share of the workforce reduces productivity by 4%.

Table 1: State-Industry Models

VARIABLES	Model 1 dln(prod.)	Model 2 dln(prod.)	Model 3 dln(prod.)	Model 4 dln(prod.)	Model 5 dln(prod.)	Model 6 dln(prod.)
Share of workforce 65+	-10.19	-10.84	-10.27	-9.28	-4.05	-4.46
<i>p-value</i>	0.00	0.00	0.00	0.00	0.02	0.01
Dlog(employment)						-0.08
<i>p-value</i>						0.07
Constant	6.33	6.24	6.39	6.45	0.02	0.02
<i>p-value</i>	0.00	0.00	0.00	0.00	0.31	0.30
First Difference					X	X
Year fixed-effects					X	X
Years	2000	2005	2010	2015	2005, 2010, 2015	2005, 2010, 2015
Observations	462	549	560	549	1,560	1,560
R-squared	0.95	0.94	0.94	0.94	0.36	0.37

Notes: Standard errors are clustered at the state level. All models include industry and state fixed effects.

Because the senior share of the workforce is still generally a minority share, the large effects on productivity suggest an impact that goes beyond merely the composition effect of

low productivity of older workers on average productivity. Even if the productivity of age 65-and-older workers was zero, then going from 3% to 6% of the workforce would decrease productivity by only 3.1% and not the 4% implied by Model 5 in Table 1.⁶ Overall, it is difficult to get large productivity changes from composition effects alone given the small share of the workforce that seniors represent.

III. Worker-Level Analysis

Individual level matched employer-employee data can be used to ensure that compositional effects are not driving the results by focusing on the effects of having older coworkers on an individual worker's wage, controlling for that worker's own age. The detailed micro-level data also allow for a variety of robustness tests. The data used in the analysis come from ADP payroll records. This includes quarterly information on all of the workers at a firm that uses ADP's payroll processing services, including age, gender and the ZIP code of a worker's residence. The data also contain firm-level industry classifications and allow for the calculation of the share of workers at a firm in a specific age group and total firm job growth over time.

Mincer regressions can be used to test the effect of firm workforce characteristics on individual worker pay while controlling for individual worker level characteristics. The basic cross-sectional regression model is defined as:

⁶Algebraically, letting the average non-senior wage = W , then the change in the average from going from 3% to 6% with a zero productivity of senior workers is: $(6\% \times 0 + 94\% \times W) - (3\% \times 0 + 97\% \times W) / (3\% \times 0 + 97\% \times W) = (94\% - 97\%) / 97\% = -3.1\%$

$$\ln(Y_{i,j,t}) = \alpha + \beta_1 X_{i,t} + \beta_2 \pi_{j,t} + \beta_3 \theta_{j,t} + \mu_{j,t} + \epsilon_{i,j,t} \quad (2)$$

where Y is the hourly wage for individual i at firm j in period t . The vector $X_{i,t}$ includes worker-specific controls, and the vector $\pi_{j,t}$ includes firm-specific controls. The variable $\theta_{j,t}$ measures the share of workers at firm j who are age 65 and older.

The basic model indicates that working at a firm with a larger share of older workers is associated with a lower wage. Model 1 in Table 2 shows the results of the model using data from the fourth quarter of 2016, but the results are robust to the time period of consideration. The results show that an increased share of firm employment age 65 and older has a statistically significant negative effect on employee wage levels. A one percentage point increase in the share of workers age 65 and older reduces wages by around 1%.

Table 2: Worker-Level Analysis - Basic Model

VARIABLES	Model 1 ln(wage)	Model 2 dln(wage)
65+ share of firm employment	-1.008*** (-0.0365)	
Change in 65+ share of firm employment		-0.0857*** (-0.0132)
Observations	914,627	914,627
R-squared	0.374	0.09

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All models include controls by 3-digit ZIP code, firm industry classification, as well as worker characteristics. Standard errors clustered at the 3-digit ZIP code level in parentheses. Sample includes all firms with 20-500 employees.

In addition, to control for persistent common factors at the firm and individual levels, the model can also compare changes in wages over a period of time to firm-level changes in the share of workers age 65 and older at the firm. The results are given in Model 2 in Table

2 and are consistent with the results from the wage-level analysis. The results shown are for a three-year time period from the fourth quarter of 2013 to the fourth quarter of 2016, but are robust across one-year, two-year, and three-year changes. The results again show a statistically significant negative effect on wage growth as a result of an increase in the share of workers at a firm age 65 and older. A 1 percentage point increase in the share of workers age 65 and older reduces wage growth by 0.0857 percentage point.

1. Albatross and Wise Man Theories

The results of these models are consistent with two opposing theories: 1) The albatross theory holds that older workers have negative productivity spillover effects, and so having more of them brings down productivity; or 2) The wise man theory holds that older workers have positive spillover effects, and firms with additional older workers have more retiring workers, and more retirements are what brings down productivity. To determine which theory is appropriate it is useful to break the stock of older workers in period t into flows from period $t - 1$ to period t :

$$\theta_{j,t} = \theta_{j,t-1} + H_{j,t} + A_{j,t} - E_{j,t} \quad (3)$$

where $\theta_{j,t}$ is the number of older workers in period t at firm j , $H_{j,t}$ is the number of older workers hired in period t , $A_{j,t}$ is the number of workers who aged into the older working group and were employed at firm j in period t and $t - 1$, and $E_{j,t}$ is the number of older workers who were employed at firm j in period $t - 1$ but exited in period t . This last term would include retirements.

Instead of including $\theta_{j,t}$ in the wage growth regression, the individual components can be included, all converted to shares by dividing by the average firm employment in periods t and $t - 1$. If older workers have negative spillovers, then $\theta_{j,t-1}$ and $A_{j,t}$ will be negative, and $E_{j,t}$ will be positive. A negative sign on $H_{j,t}$ would also be consistent with negative spillovers. However, given that firms are unlikely to hire new workers who have negative productivity spillovers, rather than simply fail to fire them as in $\theta_{j,t-1}$ and $A_{j,t}$, this suggests an indeterminate sign for $H_{j,t}$. If older workers have positive spillovers, then $\theta_{j,t-1}$ and $A_{j,t}$ will be positive and $E_{j,t}$ will be negative.

Table 3: Worker-Level Analysis - Flow Model

VARIABLES	Model 3 dln(wage)
65+ share in 2013m12 ($\theta_{j,t-1}$)	-0.0674*** (-0.0111)
65+ hires from 2013m12 to 2016m12 ($H_{j,t}$)	0.0242 (-0.019)
workers aged into 65+ share ($A_{j,t}$)	-0.0856*** (-0.0166)
65+ exits from firm over 3-yr period ($E_{j,t}$)	0.0287*** (-0.0111)
Constant	0.277*** (-0.00414)
Observations	914,627
R-squared	0.09

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All models include controls by 3-digit ZIP code, firm industry classification, as well as worker characteristics. Standard errors clustered at the 3-digit ZIP code level in parentheses.

The results are consistent with negative spillovers from older workers (see Table 3, Model 3). The coefficients on $\theta_{j,t-1}$ and $A_{j,t}$ are negative and statistically significant, and $E_{j,t}$ is positive. Wage growth is reduced as more of the workforce at a given firm ages into seniority

and wage growth picks up when older workers exit the firm. The coefficient on $H_{j,t}$ is positive, suggesting that firms on average hire older workers who do not have negative productivity spillovers, suggesting new hires are systematically different from the average older worker, although the effect is not statistically significant in this model.

IV. Robustness Tests

While first differences and firm controls help reduce omitted variable bias, it remains a possibility that firms with increasing shares of older workers experience some other negative shock over the same period that reduces wage growth but is imperfectly measured by total firm-level job growth. An additional robustness test can be performed by focusing on variation in geographic labor markets within large national firms. While the ADP data do not contain information on establishments, large firms can be divided into local labor markets by using the three-digit ZIP codes of the workers' home addresses. There are approximately 900 three-digit ZIP codes in the U.S., or about one-third the number of counties.⁷ The assumption is that workers at the same firm but in different three-digit ZIP codes work at different establishments within the same firm.

This analysis repeats Model 1 above, but measures the age 65 plus share of the workforce at firm j in a particular three-digit ZIP code. Importantly, this allows for the inclusion of firm-specific fixed effects and focuses only on within-firm wage and workforce variation. This ensures that firm-specific shocks or omitted variables are not driving the results. The sample is limited to firms with workers who live in more than 100 three-digit ZIP codes.

⁷According to the 2010 Census, there were 3,143 county or county equivalents in the United States.

The large-firm only model is robust to the addition of firm-specific fixed effects (see Table 4, Model 5), although it does slightly reduce the impact that older workers have on wages.⁸

Table 4: Worker-Level Analysis - Large Firm Test

VARIABLES	Model 4 ln(wage)	Model 5 ln(wage)
65+ share of firm employment	-1.489*** (-0.0999)	-0.626*** (-0.0936)
Firm-level fixed effects?	No	Yes
Observations	1,412,164	1,412,164
R-squared	0.601	0.712

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All models include controls by 3-digit ZIP code, as well as worker characteristics. Standard errors clustered at the 3-digit ZIP code level in parentheses. Sample includes firms with workers in 100 or more 3-digit ZIP codes.

Finally, the models are run separately for workers in 10-year age groups (see Table 5). These results reveal that having more senior coworkers has a negative effect on wages and wage growth across all age groups. The effect on wage levels is smallest for young workers, while the effect on wage growth is largest for young workers. This is consistent with younger workers having the lowest base pay and fastest wage growth, and vice versa for older workers. Importantly, these results suggest that having more senior workers at a firm reduces wages (or wage growth), even for older workers themselves.

⁸Using the sample of larger firms but not including firm-specific fixed effects (see Table 4, Model 4) yields results that are similar in magnitude to Model 1, which used a sample of smaller firms. Therefore, firm size does not appear to have a significant impact on the results.

Table 5: Worker-Level Analysis - Age Cohorts

VARIABLES	Ages <30	Age 30-39	Age 40-49	Age 50-59	Age 60-69
Dep. variable: ln(wage)					
65+ share of firm emp.	-0.419*** (-0.0426)	-0.764*** (-0.0271)	-1.021*** (-0.0263)	-1.077*** (-0.0245)	-1.018*** (-0.0319)
Observations	53,625	197,210	238,468	262,815	142,059
R-squared	0.5	0.391	0.37	0.353	0.319
Dep. variable: dln(wage)					
Δ in 65+ share of firm emp.	-0.213*** (-0.0332)	-0.170*** (-0.0192)	-0.0840*** (-0.0141)	-0.0698*** (-0.013)	-0.00657 (-0.0156)
Observations	53,625	197,210	238,468	262,815	142,059
R-squared	0.072	0.043	0.02	0.018	0.021

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All models include controls by 3-digit ZIP code, firm industry classification, as well as worker characteristics. Standard errors clustered at the 3-digit ZIP code level in parentheses. Sample includes all firms with 20-500 employees.

V. Simulating U.S. Productivity Effects

The results above suggest that the decline of U.S. productivity growth over the last 15 years and the aging of the workforce are more than coincidental. Using the coefficients from the state-industry model above, a 1-percentage point increase in the senior share is associated with 4% lower productivity. Alternatively, using the results from the worker-level analysis would suggest that a 1-percentage point increase in the senior share is associated with 1% lower productivity.

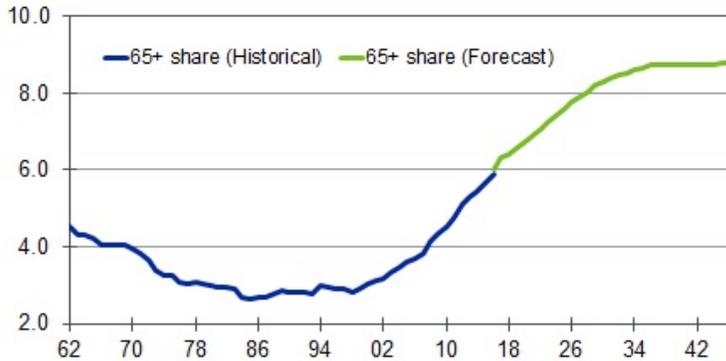
Applying these coefficients to the share of the workforce over time that is 65 and older suggests that the increase in the senior share of 3 percentage points over the last 15 years has resulted in productivity being 3% to 12% lower.⁹ In addition, the share of the workforce

⁹The future share of the workforce that is 65 and older is estimated by holding constant the current employment-to-population ratio for that age group and applying it to Moody's Analytics forecast of population growth for that cohort.

that is 65 and older will continue to rise for the foreseeable future.

Workforce Will Age Further...

Share of employed age 65 and older, %

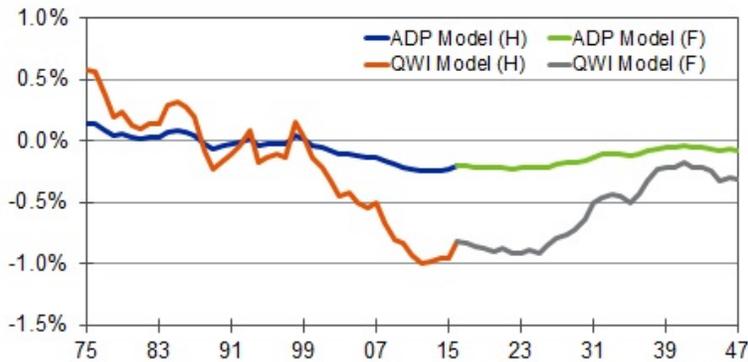


Sources: BLS, Moody's Analytics

These results imply that the aging of the workforce is currently reducing annual productivity growth by 0.25% to 1% per year, and will do so persistently for much of the next decade before starting to ease.

...Leading to Productivity Losses

Reduction in productivity growth from aging workforce, ppt



Sources: BLS, Moody's Analytics

VI. Conclusion

The state-industry panel model provides a clear and visual demonstration that productivity and aging are strongly associated using data that cover close to the full universe of private

firms and workers in the U.S. The effects are too large to be plausibly driven by worker composition effects; however, the aggregate results can best be interpreted as suggestive of an association.

Using private sector payrolls data on millions of workers allows more precise measures of the effects of firm-level workforce aging on individual wages. However, it is possible that the measured effect on wages does not reflect changes in productivity, and instead could reflect changes in rent-sharing within the firm. One plausible theory consistent with a rent-sharing effect is that older workers may prevent younger workers from receiving promotions, as they occupy top management spots and concomitant higher pay. However, the results show that having older coworkers reduces the wages of older workers as well (see Table 5), who are least likely to be crowded out of management by their own cohort. Alternatively, older workers' higher health costs may be spread to all workers and therefore reduce wages. If this were the case, the negative effect of having coworkers who are 70 and older, rather than 65 and older, would be diminished as they enroll in Medicare, but instead preliminary evidence shows that the effects grow larger with cohort age.

We cannot rule out the theory that aging changes how rents are shared within a firm without affecting productivity. However, the QWI results suggest aging does have a direct effect on productivity and not only wages. While this work can offer no conclusions here, a plausible theory is that older workers may resist productivity-improving technologies.

Distinguishing the possible mechanisms for why aging appears to affect productivity remains an open task for future research. Understanding why older workers are reducing productivity is essential if ways to mitigate the effects are to be found. The youngest baby boomers are only 53, and the aging of the workforce is far from over. This bodes poorly for

the outlook for productivity growth.

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