The Effect of Population Aging on Economic Growth

By

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Abstract

Population aging is widely expected to have detrimental effects on aggregate economic growth. However, we have little empirical evidence about the actual existence or magnitude of such effects. In this paper, we exploit differential aging patterns at the state level in the United States between 1980 and 2010. Many states have already experienced high growth rates of the 60+ population, comparable to the predicted national growth rate over the next several decades. Furthermore, these differential growth rates occur partially for reasons unrelated to economic growth, providing a natural approach to isolate the impact of aging on growth. We predict the magnitude of population aging at the state-level given the state’s age structure in an initial period and exploit this predictable differential growth to estimate the impact of population aging on Gross Domestic Product (GDP) growth, and its constituent parts, labor force and productivity growth. We estimate that a 10% increase in the fraction of the population ages 60+ decreases GDP per capita by 5.7%. We find that this reduction in economic growth caused by population aging is primarily due to a decrease in growth in the supply of labor. To a lesser extent, it is also due to a reduction in productivity growth. We present evidence of downward adjustment of earnings growth to reflect the reduction in productivity.

JEL Codes: J11, J14, J23, J26, O47

Keywords: population aging, GDP growth, demographic transitions

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The Administration on Aging projects that the fraction of the United States population age 60 or older will increase by 21% between 2010 and 2020, and by 39% between 2010 and 2050.\footnote{Data found at http://www.aoa.gov/Aging_Statistics/future_growth/future_growth.aspx (accessed on October 3, 2014).} This dramatic shift in the age structure of the U.S. population—itself the effect of the historical rise in longevity and decline in fertility—has the potential to significantly impact the performance of the macroeconomy, as well as the sustainability of government transfer programs for the aged. This potential arises from the fact that fundamental economic behaviors, such as labor supply and consumption, vary systematically over the lifecycle. People tend to consume less than they earn during the middle part of the lifecycle when they are at peak labor supply, but more than they earn during the older part of the lifecycle when they reduce labor supply and finance consumption with assets and transfers from Social Security and Medicare. Thus, as the proportion of older persons in the population increases, the number of producers (i.e., workers) in the economy tends to grow more slowly than the number of consumers.

Because labor force growth, along with growth in productivity, drives growth in economic output per capita (one measure of living standards), an aging-induced reduction in labor force growth can reduce the growth rate of economic output per capita—unless there is offsetting growth in productivity or in the size of the labor force. An important, related question is whether population aging also affects labor force productivity.

The potential macroeconomic and fiscal effects of population aging have been widely acknowledged (see National Research Council, 2012). There are, however, few
empirical estimates of the realized effect of aging on economic growth and productivity.\textsuperscript{2}

This article starts from the observation that population aging is already long underway in the United States (and in many other countries) and is playing out with varying degrees of intensity across different regions of the country, and at magnitudes that are on par with the expected future growth in the older population. For instance, across U.S. states during the period 1980 to 2010, the 10-year growth rates in the population aged 60+ ranged from -9\% to 47\%.

Our analysis leverages this substantial variation in the rate at which states are aging to estimate the effect of aging on the rate of state growth in per capita Gross Domestic Product (GDP), the state labor force participation rate, and measures of worker productivity. Naturally, there may be other factors that drive both variation in the rate of state population aging and variation in state economic outcomes; migration is one such factor. To address this, we note that a state's age structure in a given year can be used to predict the fraction of the population that will be 60 or above in ten years. We use this variation in predictable aging to estimate a causal impact of aging on GDP growth.

Our estimates imply that a 10\% increase in the fraction of the population ages 60+ decreases growth in GDP per capita by 5.7\%. Decomposing the growth rate in GDP per capita into its constituent parts—the change in labor force participation and the change in productivity—we observe that most of the reduction in GDP growth is driven by reductions in labor supply, as measured by workers per capita, hours worked per capita, and labor earnings per capita.

\textsuperscript{2} A small number of studies have sought to forecast the effects of aging on future economic performance (see e.g., Borsch-Supan, 2003 and National Research Council, 2012).
We also find that some of the effect of aging on GDP growth can be attributed to reductions in productivity growth, as measured in the standard way by growth in GDP per worker and growth in GDP per labor hour worked. However, we observe no effect of population aging on changes in GDP per labor dollar earned. If earnings are proportional to labor productivity, they should adjust in response to changes in the skill composition and productivity of the work force. The absence of an effect of aging on productivity when we adjust for the standard measure for the value of labor inputs may suggest that the labor market has in fact adjusted to the reduction in productivity growth.

This result may also tell us something about the relative skills of the outgoing and incoming labor force cohorts during the period we examine from 1980-2010. One interpretation consistent with our results is that the older cohorts leaving the labor force were more productive than the younger cohorts entering the labor force. Alternatively, even if it were the case that the outgoing older cohorts were individually less productive (consistent with education and skill differences across birth cohorts), it is possible that their presence created positive production spillovers on younger workers.

Finally, we show that the reduction in economic growth caused by population aging during this period was not concentrated in particular industries. Instead, we find evidence that industries were affected by aging relatively uniformly.

In the next section, we discuss population aging in the United States and the literature on the economic impacts of aging. In Section II, we discuss our data, followed by our empirical strategy in Section III. The results are presented in Section IV. We conclude in Section V.

I. Background
Population Aging in Aggregate and across U.S. States

Figure 1 shows the percent of the U.S. population aged 60 and older between 1900 and 2000, and the projected percent through 2050, based on data from the U.S. Census Bureau. The figure shows how the population has aged nearly continuously over the 100-year period from 1900 to 2010. The U.S. population is projected to continue aging, at a relatively faster rate through 2030 (driven by the aging of the baby boom) and at a slower rate thereafter. Our analysis period is 1980-2010, which is notable in that it includes not only two decades of substantial growth in the population age 60+ but also the only decade in which the percent of population age 60+ actually declined between 1990 and 2000 (due to the baby boom “bulge” passing through the middle of the age distribution).

In Figure 2, we show the variation in the growth rate of the 60+ population for each state (excluding Alaska and Hawaii) and D.C. between 1980 and 1990. During this period of overall growth in the population 60+, there was substantial variation in the rate of aging across states. While Wyoming experienced a 15% growth in the percent of its population 60+, 15 states actually experienced decreases. We observe less population aging between 1990 and 2000 in Figure 3 as the majority of states actually experienced declines in the percent of their population 60+. However, between 2000 and 2010, Figure 4 shows that there was significant population aging. The growth rate of the older population was above 15% for 20 states while 4 states experienced less than a 5% increase.

If migration and mortality were entirely independent of economic changes, then it would be useful to compare the economic outcomes of states with significant population aging to states with less population aging. Instead, there are many reasons that states experience relative changes in population aging including differential migration rates for
younger or older people and differential mortality rates. Given that these are possibly correlated with secular economic trends, correlations between economic growth and older population growth at the state level may not represent the causal impact of population aging. Instead, we pursue a strategy that uses a state’s age structure to predict population aging. In short, we would expect that a state with a disproportionate share of its population in the 50-59 age group will experience faster growth in the fraction of its population that is 60+ over the next decade.

**Literature**

While we do not know of any study that has estimated realized effects of population aging on economic outcomes in the United States, a small literature has considered this relationship in the international context. Feyrer (2007) highlights the rarity of the growth literature to study the possible impacts of age structure. Feyrer (2007) provides some of the first evidence by using differential changes in the workforce age structure across different countries, finding that age structure is a strong predictor of aggregate productivity. This paper, however, assumes that population age structure changes are unrelated to economic growth, an assumption which may be more plausible in an international context. However, there are still concerns that differential immigration or the mortality impacts of economic growth could confound these estimates.

Other studies in the growth literature have considered the importance of the “dependency ratio” without focusing on aging more specifically. Bloom, Canning, and Sevilla (2003) discusses the importance of the sizes of the 15-64 and 25-59 age groups relative to total population. Kögel (2005) measures the effect of changes in the youth dependency ratio on total factor productivity.
The contributions of this paper are to provide population aging estimates specific to the United States while introducing a straightforward instrumental variable strategy. This strategy should reduce concerns that confounding variables resulting from migration or mortality are driving the results.

II. Data

We use data from the Census and American Community Survey (ACS) to construct state age, employment, and industry profiles. We use the 1980, 1990, and 2000 Census, combined with the 2009-2011 American Community Surveys. Due to the relative smaller size of the ACS, we aggregate the 2009-2011 samples to construct a “2010 Census.” The Census data provide individual-level information on labor outcomes such as employment status and labor earnings. We also use the industry variables to construct measures of the industry composition of each state in every year. We aggregate to the state-year level using the individual-level weights.

The Bureau of Economic Analysis (BEA) provides annual GDP data at the state level. State GDP is defined as “the value added in production by the labor and capital located in a state,” measured in dollars. These data “provide a comprehensive measure of a state’s production” and “are used widely in both the public and private sectors” (BEA, 2006). We use the state as our unit of observation because GDP information for smaller geographic areas is not available for a long enough time trend. The state GDP data include industry-specific output measures, which we will also use to study the differential impacts of aging on different sectors of the economy.

The BEA also provides data on employee compensation. Compensation measures both wages paid to employees and noncash benefits. Wages are the primary component of
employee compensation and include sick pay, vacation pay, severance pay, commission, etc. Noncash benefits include in-kind benefits and employer contributions to pension plans, health insurance, and social insurance programs. We use the Census data to calculate total labor earnings, and we use the BEA employee compensation measure as the full cost of labor in the state.

III. Empirical Strategy

Our primary specification is

\[
y_{s,t+10} - y_{st} = \gamma_t + \beta \left[ \ln \left( \frac{A_{s,t+10}}{N_{s,t+10}} \right) - \ln \left( \frac{A_{st}}{N_{st}} \right) \right] + X'_s \delta_t + \varepsilon_{st},
\]

where \( y_{st} \) is an economic outcome measures for state \( s \) in year \( t \). \( A \) is the total number of older individuals, which we define as individuals aged 60 and older. \( N \) represents the total population aged 20 and older. \( X \) includes a set of time-varying control variables. We control for initial (period \( t \)) industry composition of the labor force and we allow these variables to have a differential effect for each decade. Specifically, we control for the log of the fraction of workers in each industry. We believe that these controls are useful given the differential growth rates of geographic areas based on initial industry composition. Since industry growth has varied over time, we allow for a differential effect in each decade. All specifications are estimated in 10-year differences and we adjust all standard errors for clustering at the state level. For most of our analysis, the outcome variable is the log of GDP per person aged 20+. However, we will also use other economic outcome metrics to explore which components of per capita GDP are changing due to exogenous population aging.
While this specification relates changes in state population aging to changes in state economic outcomes, the demographics of a state may depend on economic growth. Economic decline could induce prime-aged workers to migrate out of the state while older workers may be more likely to stay given the smaller lifetime return to moving. Consequently, we would observe that aging states are associated with poor economic outcomes, though this relationship is not causal.

Instead, we pursue instrumental variable estimation of equation (1), which exploits the differential and predictable aging patterns of the different states over time. Given the period $t$ age composition of a state, we can predict which states will experience an increase in the fraction of their population that is 60+. Using the Census data, we first construct national aging ratios, the “survival ratio” of a cohort from each Census to the subsequent Census. This ratio provides the size of a cohort in 1990 relative to 1980, 2000 relative to 1990, and 2010 relative to 2000. There are several reasons that this ratio can vary including mortality, immigration, and sampling variation. We construct these national ratios for every single age. We fix these ratios for each decade and use them to predict each state’s age structure in the next Census. For example, to predict the number of 64 year olds in Alabama in 2000, we multiply the number of 54 year olds in Alabama in 1990 by the national ratio of 64 year olds in 2000 to 54 year olds in 1990. This approach uses initial state composition interacted with national level cohort changes. The advantage of this instrument is that it eliminates differential state-level migration and mortality for identification. The components of the instruments are constructed in the following manner:
where \( a \) represents age. The instrument is the predicted change in the log of the fraction of the state population 60+:

\[
\ln \left( \frac{\hat{A}_{s,t+10}}{\bar{N}_{s,t+10}} \right) - \ln \left( \frac{A_{st}}{N_{st}} \right)
\]

A primary source of variation is that states vary in the relative sizes of their age 50-59 cohort. States with a large fraction of 50-59 years olds are predicted to experience relatively large increases in older individuals.

In Figures 2-4, we showed that states varied substantially in the growth rate of the older population. We also observe in our data that these differential growth rates were predictable. In Figures 5-7, we graph our predicted growth in aging with the actual growth rate experienced by the state. Figure 5 shows this relationship for 1980-1990. There is a clear and strong relationship between the two variables. A similar relationship can be seen in Figure 6 for 1990-2000. The strongest relationship is observed in Figure 7 for the growth rates between 2000 and 2010. We find that a one percentage increase in the predicted growth rate of the 60+ population is associated with a 0.627 percentage increase in the actual growth rate. This relationship is critical to our empirical strategy.

Note that our specification is estimated in differences, accounting for the fixed impact of the state’s initial age composition. We also include year effects to control for
common economic trends, which may be correlated with the national cohort ratios used in our instruments.

We present summary statistics in Table 1. In each sample year, there is significant variation in both the actual growth rate of the 60+ population and the predicted growth rate. Table 1 also illustrates that state economic growth rates vary substantially within each sample year.

IV. Results

We first estimate equation (1) using ordinary least squares, establishing the relationship between state-level population aging and economic growth. The dependent variable is the change in log per capita GDP. Table 2 presents these results. We observe that states experiencing growth in the fraction of individuals ages 60+ also experience slower growth in per capita GDP. Using the full sample, we estimate that a 10% increase in population aging (defined as growth in the fraction of the state population aged 60+) is associated with a decrease in economic growth of 7.5%. Limiting the sample to one ten-year difference at a time, we consistently find large and statistically significant relationships.

As discussed above, there are many reasons that states may age at different rates and economic growth could directly impact migration decisions. Instead, we examine the relationship between our instrument – the predicted change in the log of the fraction of individuals 60+ in a state – and economic growth. The results are presented in Table 3. We find statistically significant negative effects. The full sample estimate implies that a 10% increase in the predicted fraction of the 60+ population decreases per capita GDP growth
by 4.1%. When we focus on just one ten-year difference at a time, we consistently estimate negative effects.

We previously showed graphical evidence that our instrument predicts actual population aging at the state level. We present regression estimates in Table 4, which condition on the industry composition controls. Table 4 shows that the instruments predict population aging in each sample. For each 10% increase in the growth of the 60+ population, a state actually experiences a 7.2% increase. We can scale our reduced form results with our first stage estimates. The corresponding instrumental variable estimates are presented in Table 5. We present these results while weighting by population (in the top row) and results without weighting (bottom row). Using the full sample, we estimate that a 10% increase in population aging decreases economic growth by 5.7%. These results do not depend on the weighting scheme. Without weighting, we estimate an effect of 6.5%. We find consistent results for each sample, regardless of weights.

We next explore the mechanisms driving these large effects on economic growth per capita. We decompose the change in log of GDP per capita into a productivity component and a labor supply component. As described earlier, both of these components are potentially impacted by population aging. An aged population may be less productive even conditional on working. Alternatively, it is possible that older individuals - if they work - are actually more productive given their experience. An older population is also less likely to work and should have a direct impact on the total labor supply of the state, impacting per capita output.

We divide our economic growth measure into these two components in different ways, each of which will provide useful information about the mechanisms driving the
reduced economic growth. First, we decompose our outcome variable using \( \ln \left( \frac{GDP}{N} \right) = \ln \left( \frac{GDP}{L} \right) + \ln \left( \frac{L}{N} \right) \), where \( L \) is the total number of workers in the state. The first component is the log of GDP per worker, a measure of output per worker, or productivity. The second component is the log of the employment rate (which we define as total number of workers divided by the total state population). We estimate equation (1) using both of these outcomes. The resulting coefficients will mechanically add to the results presented in the first row of Table 5.

We present these decompositions in Table 6. Our first set of results includes evidence that population aging affects both components. A 10% increase in population aging decreases the growth rate of GDP per worker by 4.0% and the growth in the employment rate by 1.7%. However, we can refine these measures further. GDP per worker may be decreasing to such a large extent because hours per worker are impacted by population aging.

Consequently, we decompose our main outcome measure using \( \ln \left( \frac{GDP}{N} \right) = \ln \left( \frac{GDP}{H} \right) + \ln \left( \frac{H}{N} \right) \), where \( H \) represents the total number of hours worked. We find some evidence that output per hour worked is less affected than output per worker. Using these measures, we estimate a productivity reduction due to a 10% increase in population aging of 3.7% and a labor supply reduction of 2.0%.

Still, hours worked also does not encompass all components of labor supply. Instead, we use labor earnings as a measure of labor supply. We study GDP per labor dollar earned as a measure of the output generated for each dollar paid to workers in the state. We find no statistical relationship with respect to this outcome. Instead, we find that
population aging reduces labor earnings per person in a state, consistent with an equilibrium adjustment to the effect of aging on output per worker. A state which experiences an increase in the 60+ population has fewer workers and these workers work less, but they do not earn a disproportionate amount given their marginal output. Our results may also suggest that the productivity and skill profile of those who do work, is affected by population aging. This could arise from relative skill differences between the outgoing and incoming labor force cohorts, or from the loss of positive spillovers from older to younger workers.

Finally, labor earnings do not encompass all forms of labor compensation. We use data from the BEA on state-level compensation costs, which include a broader measure of firm-level payments – monetary and in-kind – to workers. Here, we find similar evidence of adjustment to the slowing of productivity growth, as measured by GDP per dollar of total compensation. An additional dollar paid to workers in a state with a higher fraction of older individuals does not produce less output. Instead, these older states have less compensation per person. These results are relatively consistent in each sample, though we do find some evidence of incomplete adjustment during the period 2000-2010, which may reflect the effects of the Great Recession.

It also of interest to examine the effect of population aging on the labor supply of different age groups. We estimate equation (1) using the change in the log of the employment rate by age group as the outcome variable. We present the results by age group and gender in Table 7. We find little effect of population aging on employment growth at younger ages, but larger effects at older ages. The results suggest that an increase in the fraction of the population that is 60+ crowds out older workers. While we
find a decrease in labor supply overall, these results suggest that these reductions were limited to older individuals. Our estimates are consistent with the idea that older workers crowd out other older workers but have little effect on younger workers.

Table 8 presents the corresponding wage effects. Here, we find large effects on younger workers. The outcome variable is the change in the log wage, which is defined as total labor earnings divided by total hours worked (by age group, gender, state, and year). These results imply that an aging labor force reduces productivity at younger ages. This could arise if the older cohorts leaving the labor force were more productive than younger cohorts, or from the loss of positive production spillovers from older to younger workers. In this analysis, we cannot account for the full compensation costs since the BEA does not estimate compensation data by age group. Using the wage, we find that younger workers are most impacted by population aging. The Table 7 and 8 results also suggest that older and younger workers are complements in production, rather than substitutes.

While we have focused on total state GDP per capita, we can also look at industry-specific output per person. It is possible that population aging affects different industries to varying degrees. We use the BEA data on industry-specific GDP to study the relationship between aging and growth in output by industry. We present the estimates in Table 9. We first estimate the effect of population aging on the output of all private industries and find a similar effect as our main estimate. This result implies that our findings are not driven by different changes in public sector output.

When examining specific industries, we find that our largest estimate corresponds to construction output. We estimate that a 10% increase in state population aging decreases growth in construction output per capita by 8.9%. We also find a statistically
significant reduction on growth in transportation/utilities, wholesale trade, retail trade, finance/insurance, and services. The decrease in overall growth cannot be explained by a reduction in growth in one or a small number of industries. Instead, it appears that the effect is relatively uniform across industries.

One concern of our identification strategy is that states which are predicted to experience a large increase in the fraction aged 60+ may have different age structures at other points of the distribution. The economic outcomes of the state may also depend on the growth of these age groups. We can test for this possibility explicitly given that our instrumental variables strategy can also predict growth in other age groups. We include multiple age groups at a time in our specification and, as before, estimate out main model using two-stage least squares, where the instruments are the predicted changes in each included age group using the same method to predict changes as before. We do not use a log transformation of our explanatory variables here because the age groups are different sizes and a 10% increase in the size of the 60+ population is different than a 10% increase in the 40-49 population. The excluded age group is the 20-29 age group. The results are presented in Table 10. We find that only the 60+ population is associated with a statistically significant decrease in growth in GDP per capita. When we include all other age groups, we estimate that each additional percentage point growth in the population that is 60+ decreases growth in per capita output by 0.2 percent. Including or excluding the other age groups has little effect on this estimate. Consequently, we conclude that separately identifying these other age groups is not necessary for consistent estimation in our context.
We also test the robustness of our results to functional form assumptions. Silva and Tenreyo (2006) show that a log-linear specification assumes that the error term is multiplicative in the outcome variable. Nonlinear least squares estimation using an exponential specification and Poisson regression relaxes this assumption, allowing for a multiplicative and additive error term. We replicate our main analysis using nonlinear least squares and present the results in Table 11. We find similar results as before, suggesting that our results are not driven by functional form assumptions.

V. Conclusion

We estimate a statistically significant negative relationship between population aging growth and output growth at the state level in the United States between 1980 and 2010. Over this time period and across states, we observe substantial variation in population aging, including aging growth rates comparable to rates forecasted for the United States in the near future. Our estimates imply that a 10% increase in the fraction of the population ages 60+ decreases growth in GDP per capita by 5.7%. While our results suggest large reductions in economic growth associated with population aging at the state-level, our estimates do not account for any broader spillovers at the national level. Population aging may induce broader equilibrium effects that we cannot capture such as federal tax increases. Overall, we expect our estimates to actually underestimate the overall effect on the economic growth of the United States.

We attribute most of the estimated effect to a slowdown in labor supply growth. However, we also find that some of the effect can be attributed to reductions in output per worker and output per hours worked. We find little evidence that our estimate effect is driven by one time period or that the growth reductions of population aging or limited to
just one or two major industries. Instead, the effects are rather consistent over time and uniform across industries.
Figures

Figure 1: Percent of United States Population Age 60+: Actual and Projected – 1900-2050

Source: U.S. Census Bureau, compiled by U.S. Administration on Aging.

Figure 2: Growth Rate in Age 60+ Population by State: 1980-1990

Notes: We use 1980 and 1990 Census data to construct the fraction of each state’s population ages 60+. This map refers to the percentage change in this metric between 1980 and 1990.
Figure 3: Growth Rate in Age 60+ Population by State: 1990-2000

Notes: We use 1990 and 2000 Census data to construct the fraction of each state’s population ages 60+. This map refers to the percentage change in this metric between 1990 and 2000.

Figure 4: Growth Rate in Age 60+ Population by State: 2000-2010

Notes: We use 2000 and 2010 Census data to construct the fraction of each state’s population ages 60+. This map refers to the percentage change in this metric between 2000 and 2010.
Figure 5: Relationship between Instrument and Aging Growth: 1980-1990

![Graph showing the relationship between instrument and aging growth from 1980 to 1990. The slope is 0.500***.]

Notes: We use 1980 and 1990 Census data to construct the fraction of each state’s population which is ages 60+.

Figure 6: Relationship between Instrument and Aging Growth: 1990-2000

![Graph showing the relationship between instrument and aging growth from 1990 to 2000. The slope is 0.415***.]

Notes: We use 1990 and 2000 Census data to construct the fraction of each state’s population which is ages 60+.
Figure 7: Relationship between Instrument and Aging Growth: 2000-2010

Notes: We use 2000 and 2010 Census data to construct the fraction of each state’s population which is ages 60+.
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“GDP per dollar earner” refers to GDP divided by total labor earnings.
“GDP per compensation cost” refers to GDP divided by total compensation to employee (wages and in-kind benefits).
### Table 2: OLS Estimation

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Notes: Significance Levels: *10%, **5%, ***1%. Standard errors in parentheses adjusted for clustering at state level. Each observation is weighted by period t population. Other variables included: year dummies; the log of the fraction of workers in period t working in each of the following industries: agriculture, mining, construction, manufacturing, transportation, communications / utilities, wholesale trade, retail trade, finance / insurance / real estate, business and repair services, personal services, recreation services, professional services, and public administration. The effects of these industry composition variables are allowed to vary by year.

### Table 3: Effect of Predicted Aging Changes on GDP Growth

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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>△ ln((\frac{A}{N}))</td>
<td></td>
<td>-0.407***</td>
<td>-0.647***</td>
<td>-0.286</td>
<td>-0.339**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.151)</td>
<td>(0.213)</td>
<td>(0.356)</td>
<td>(0.149)</td>
</tr>
<tr>
<td>N</td>
<td></td>
<td>153</td>
<td>51</td>
<td>51</td>
<td>51</td>
</tr>
</tbody>
</table>

Notes: Significance Levels: *10%, **5%, ***1%. Standard errors in parentheses adjusted for clustering at state level. Each observation is weighted by period t population. Other variables included: year dummies; the log of the fraction of workers in period t working in each of the following industries: agriculture, mining, construction, manufacturing, transportation, communications / utilities, wholesale trade, retail trade, finance / insurance / real estate, business and repair services, personal services, recreation services, professional services, and public administration. The effects of these industry composition variables are allowed to vary by year.
Table 4: First Stage

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Δ ln((\frac{A}{N}))</td>
<td>0.716***</td>
<td>0.627***</td>
<td>0.504***</td>
<td>0.865***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.045)</td>
<td>(0.099)</td>
<td>(0.133)</td>
<td>(0.059)</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>153</td>
<td>51</td>
<td>51</td>
<td>51</td>
<td></td>
</tr>
</tbody>
</table>

Notes: Significance Levels: *10%, **5%, ***1%. Standard errors in parentheses adjusted for clustering at state level. Each observation is weighted by period t population. Other variables included: year dummies; the log of the fraction of workers in period t working in each of the following industries: agriculture, mining, construction, manufacturing, transportation, communications / utilities, wholesale trade, retail trade, finance / insurance / real estate, business and repair services, personal services, recreation services, professional services, and public administration. The effects of these industry composition variables are allowed to vary by year.

Table 5: Instrumental Variable Estimates: Effect of Aging on GDP Growth

<table>
<thead>
<tr>
<th>Dependent Variable:</th>
<th>Δ ln (GDP / N)</th>
<th>Weighted by Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Δ ln((\frac{A}{N}))</td>
<td>-0.569***</td>
<td>-1.032***</td>
</tr>
<tr>
<td></td>
<td>(0.199)</td>
<td>(0.393)</td>
</tr>
<tr>
<td>N</td>
<td>153</td>
<td>51</td>
</tr>
</tbody>
</table>

| Δ ln(\(\frac{A}{N}\)) | -0.651*** | -0.965**  | -0.763**  | -0.438*** |
|                     | (0.174)   | (0.395)   | (0.298)   | (0.145)   |
| N                   | 153       | 51        | 51        | 51        |

Notes: Significance Levels: *10%, **5%, ***1%. Standard errors in parentheses adjusted for clustering at state level. Other variables included: year dummies; the log of the fraction of workers in period t working in each of the following industries: agriculture, mining, construction, manufacturing, transportation, communications / utilities, wholesale trade, retail trade, finance / insurance / real estate, business and repair services, personal services, recreation services, professional services, and public administration. The effects of these industry composition variables are allowed to vary by year.
<table>
<thead>
<tr>
<th></th>
<th>ln(GDP/L)</th>
<th>ln(L/N)</th>
<th>ln(GDP/H)</th>
<th>ln(H/N)</th>
<th>ln(GDP / Earnings)</th>
<th>ln(Earnings / N)</th>
<th>ln(GDP / Compensation)</th>
<th>ln(Compensation / N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Δ ln((\frac{\Delta}{N}))</td>
<td>-0.397**</td>
<td>-0.172**</td>
<td>-0.366**</td>
<td>-0.202***</td>
<td>-0.029</td>
<td>-0.540***</td>
<td>-0.169</td>
<td>-0.400***</td>
</tr>
<tr>
<td></td>
<td>(0.195)</td>
<td>(0.039)</td>
<td>(0.185)</td>
<td>(0.051)</td>
<td>(0.116)</td>
<td>(0.137)</td>
<td>(0.152)</td>
<td>(0.124)</td>
</tr>
<tr>
<td>1980-1990</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Δ ln((\frac{\Delta}{N}))</td>
<td>-0.767**</td>
<td>-0.325***</td>
<td>-0.811**</td>
<td>-0.221**</td>
<td>-0.052</td>
<td>-0.979***</td>
<td>-0.113</td>
<td>-0.919***</td>
</tr>
<tr>
<td></td>
<td>(0.389)</td>
<td>(0.096)</td>
<td>(0.380)</td>
<td>(0.119)</td>
<td>(0.180)</td>
<td>(0.293)</td>
<td>(0.363)</td>
<td>(0.238)</td>
</tr>
<tr>
<td>1990-2000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Δ ln((\frac{\Delta}{N}))</td>
<td>-0.361</td>
<td>-0.205***</td>
<td>-0.152</td>
<td>-0.414***</td>
<td>-0.365</td>
<td>-0.201</td>
<td>0.067</td>
<td>-0.634**</td>
</tr>
<tr>
<td></td>
<td>(0.558)</td>
<td>(0.060)</td>
<td>(0.623)</td>
<td>(0.118)</td>
<td>(0.275)</td>
<td>(0.436)</td>
<td>(0.371)</td>
<td>(0.310)</td>
</tr>
<tr>
<td>2000-2010</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Δ ln((\frac{\Delta}{N}))</td>
<td>-0.288**</td>
<td>-0.104***</td>
<td>-0.257**</td>
<td>-0.136**</td>
<td>0.075</td>
<td>-0.468***</td>
<td>-0.257**</td>
<td>-0.136</td>
</tr>
<tr>
<td></td>
<td>(0.154)</td>
<td>(0.039)</td>
<td>(0.143)</td>
<td>(0.065)</td>
<td>(0.123)</td>
<td>(0.110)</td>
<td>(0.133)</td>
<td>(0.130)</td>
</tr>
</tbody>
</table>

Notation: \(L\) = number of workers; \(H\) = total number of hours worked; \(Earnings\) = total labor earnings; \(Compensation\) = total compensation paid to workers.

Notes: Significance Levels: *10%, **5%, ***1%. Standard errors in parentheses adjusted for clustering at state level. Each observation is weighted by period \(t\) population. The coefficients presented in each two columns (in the same row) add up to the main effect (see Table 6). Other variables included: year dummies; the log of the fraction of workers in period \(t\) working in each of the following industries: agriculture, mining, construction, manufacturing, transportation, communications / utilities, wholesale trade, retail trade, finance / insurance / real estate, business and repair services, personal services, recreation services, professional services, and public administration. The effects of these industry composition variables are allowed to vary by year.
Table 7: Age-Specific Labor Outcomes: Change in Log of Employment Rate

<table>
<thead>
<tr>
<th>Ages</th>
<th>20-29</th>
<th>30-39</th>
<th>40-49</th>
<th>50-59</th>
<th>60-69</th>
<th>70-79</th>
<th>80-89</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Δ ln(A/N)</td>
<td>-0.003</td>
<td>-0.014</td>
<td>0.015</td>
<td>-0.082*</td>
<td>-0.313***</td>
<td>-0.447**</td>
<td>-0.762***</td>
</tr>
<tr>
<td></td>
<td>(0.045)</td>
<td>(0.027)</td>
<td>(0.022)</td>
<td>(0.043)</td>
<td>(0.117)</td>
<td>(0.200)</td>
<td>(0.278)</td>
</tr>
<tr>
<td>N</td>
<td>153</td>
<td>153</td>
<td>153</td>
<td>153</td>
<td>153</td>
<td>153</td>
<td>153</td>
</tr>
<tr>
<td>Women</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Δ ln(A/N)</td>
<td>0.018</td>
<td>-0.071</td>
<td>-0.026</td>
<td>-0.037</td>
<td>-0.241*</td>
<td>-0.132</td>
<td>-0.702*</td>
</tr>
<tr>
<td></td>
<td>(0.050)</td>
<td>(0.045)</td>
<td>(0.050)</td>
<td>(0.059)</td>
<td>(0.124)</td>
<td>(0.269)</td>
<td>(0.411)</td>
</tr>
<tr>
<td>N</td>
<td>153</td>
<td>153</td>
<td>153</td>
<td>153</td>
<td>153</td>
<td>153</td>
<td>153</td>
</tr>
</tbody>
</table>

Notes: Significance Levels: *10%, **5%, ***1%. Standard errors in parentheses adjusted for clustering at state level. Each observation is weighted by period t population. Other variables included: year dummies; the log of the fraction of workers in period t working in each of the following industries: agriculture, mining, construction, manufacturing, transportation, communications / utilities, wholesale trade, retail trade, finance / insurance / real estate, business and repair services, personal services, recreation services, professional services, and public administration. The effects of these industry composition variables are allowed to vary by year.
Table 8: Age-Specific Labor Outcomes: Change in Log of Wage

<table>
<thead>
<tr>
<th>Ages</th>
<th>20-29</th>
<th>30-39</th>
<th>40-49</th>
<th>50-59</th>
<th>60-69</th>
<th>70-79</th>
<th>80-89</th>
</tr>
</thead>
<tbody>
<tr>
<td>Δ ln((\frac{4}{N}))</td>
<td>-0.422***</td>
<td>-0.325***</td>
<td>-0.402***</td>
<td>-0.477***</td>
<td>-0.498***</td>
<td>0.129</td>
<td>0.429</td>
</tr>
<tr>
<td></td>
<td>(0.150)</td>
<td>(0.119)</td>
<td>(0.113)</td>
<td>(0.096)</td>
<td>(0.107)</td>
<td>(0.261)</td>
<td>(0.507)</td>
</tr>
<tr>
<td></td>
<td>153</td>
<td>153</td>
<td>153</td>
<td>153</td>
<td>153</td>
<td>153</td>
<td>153</td>
</tr>
</tbody>
</table>

Women

<table>
<thead>
<tr>
<th>Ages</th>
<th>20-29</th>
<th>30-39</th>
<th>40-49</th>
<th>50-59</th>
<th>60-69</th>
<th>70-79</th>
<th>80-89</th>
</tr>
</thead>
<tbody>
<tr>
<td>Δ ln((\frac{4}{N}))</td>
<td>-0.342**</td>
<td>-0.404***</td>
<td>-0.376***</td>
<td>-0.433***</td>
<td>-0.324**</td>
<td>0.045</td>
<td>0.712</td>
</tr>
<tr>
<td></td>
<td>(0.135)</td>
<td>(0.137)</td>
<td>(0.123)</td>
<td>(0.123)</td>
<td>(0.125)</td>
<td>(0.276)</td>
<td>(0.641)</td>
</tr>
<tr>
<td></td>
<td>153</td>
<td>153</td>
<td>153</td>
<td>153</td>
<td>153</td>
<td>153</td>
<td>153</td>
</tr>
</tbody>
</table>

Notes: Significance Levels: *10%, **5%, ***1%. Standard errors in parentheses adjusted for clustering at state level. Each observation is weighted by period t population. Other variables included: year dummies; the log of the fraction of workers in period t working in each of the following industries: agriculture, mining, construction, manufacturing, transportation, communications / utilities, wholesale trade, retail trade, finance / insurance / real estate, business and repair services, personal services, recreation services, professional services, and public administration. The effects of these industry composition variables are allowed to vary by year.

Table 9: Effect of Aging on Industry-Specific GDP

<table>
<thead>
<tr>
<th>Private Industries</th>
<th>Mining</th>
<th>Construction</th>
<th>Manufacturing</th>
<th>Transportation / Utilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Δ ln((\frac{4}{N}))</td>
<td>-0.617***</td>
<td>0.219</td>
<td>-0.893***</td>
<td>-0.230</td>
</tr>
<tr>
<td></td>
<td>(0.224)</td>
<td>(1.654)</td>
<td>(0.322)</td>
<td>(0.429)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Wholesale Trade</th>
<th>Retail Trade</th>
<th>Finance / Insurance</th>
<th>Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Δ ln((\frac{4}{N}))</td>
<td>-0.533***</td>
<td>-0.461***</td>
<td>-0.582**</td>
</tr>
<tr>
<td></td>
<td>(0.196)</td>
<td>(0.156)</td>
<td>(0.265)</td>
</tr>
</tbody>
</table>

Notes: Significance Levels: *10%, **5%, ***1%. Standard errors in parentheses adjusted for clustering at state level. Each observation is weighted by period t population. The outcome is the log of industry-specific GDP per person in the state. Other variables included: year dummies; the log of the fraction of workers in period t working in each of the following industries: agriculture, mining, construction, manufacturing, transportation, communications / utilities, wholesale trade, retail trade, finance / insurance / real estate, business and repair services, personal services, recreation services, professional services, and public administration. The effects of these industry composition variables are allowed to vary by year.
### Table 10: Effects of Other Age Groups

<table>
<thead>
<tr>
<th>Dependent Variable:</th>
<th>Δ ln (GDP / N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Δ (Ages 30-39 / N)</td>
<td>-0.210</td>
</tr>
<tr>
<td></td>
<td>(0.843)</td>
</tr>
<tr>
<td>Δ (Ages 40-49 / N)</td>
<td>-0.980</td>
</tr>
<tr>
<td></td>
<td>(0.946)</td>
</tr>
<tr>
<td></td>
<td>-0.931</td>
</tr>
<tr>
<td></td>
<td>(0.938)</td>
</tr>
<tr>
<td>Δ (Ages 50-59 / N)</td>
<td>-0.601</td>
</tr>
<tr>
<td></td>
<td>(1.414)</td>
</tr>
<tr>
<td></td>
<td>-0.451</td>
</tr>
<tr>
<td></td>
<td>(1.238)</td>
</tr>
<tr>
<td></td>
<td>-0.503</td>
</tr>
<tr>
<td></td>
<td>(1.250)</td>
</tr>
<tr>
<td>Δ (Ages 60+ / N)</td>
<td>-1.960**</td>
</tr>
<tr>
<td></td>
<td>(0.920)</td>
</tr>
<tr>
<td></td>
<td>-1.878**</td>
</tr>
<tr>
<td></td>
<td>(0.785)</td>
</tr>
<tr>
<td></td>
<td>-1.802**</td>
</tr>
<tr>
<td></td>
<td>(0.803)</td>
</tr>
<tr>
<td></td>
<td>-1.921**</td>
</tr>
<tr>
<td></td>
<td>(0.877)</td>
</tr>
</tbody>
</table>

N 153 153 153 153

Notes: Significance Levels: *10%, **5%, ***1%. Standard errors in parentheses adjusted for clustering at state level. Each observation is weighted by period t population. Other variables included: year dummies; the log of the fraction of workers in period t working in each of the following industries: agriculture, mining, construction, manufacturing, transportation, communications / utilities, wholesale trade, retail trade, finance / insurance / real estate, business and repair services, personal services, recreation services, professional services, and public administration. The effects of these industry composition variables are allowed to vary by year.

### Table 11: Instrumental Variable Poisson Estimates: Effect of Aging on GDP Growth

<table>
<thead>
<tr>
<th>Dependent Variable:</th>
<th>GDP / N</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-0.575*** -1.331*** -0.711 -0.413***</td>
</tr>
<tr>
<td></td>
<td>(0.175) (0.455) (0.504) (0.141)</td>
</tr>
</tbody>
</table>

N 153 51 51 51

Notes: Significance Levels: *10%, **5%, ***1%. Standard errors in parentheses adjusted for clustering at state level. Each observation is weighted by period t population. Period t GDP per capita is included as an offset (the coefficient is constrained to equal 1). Other variables included: year dummies; the log of the fraction of workers in period t working in each of the following industries: agriculture, mining, construction, manufacturing, transportation, communications / utilities, wholesale trade, retail trade, finance / insurance / real estate, business and repair services, personal services, recreation services, professional services, and public administration. The effects of these industry composition variables are allowed to vary by year.
References


