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Combatting the economic
impact of ageing through
productivity growth?

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Taku Honiden,
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Ageing and productivity growth in OECD regions

Combatting the economic impact of ageing through productivity growth?

By: Federica Daniele, Taku Honiden and Alexander C. Lembcke

OECD countries and their regions are ageing fast. In principle, the negative impact of ageing on the growth rate of per capita gross domestic product could be offset by increases in productivity. However, for many regions, productivity growth required to maintain per capita GDP levels constant has been higher than the actual growth rates they recorded in the past years. One reason for this is that ageing also has a direct negative impact on productivity growth, with the effect being concentrated in urban areas. One possible explanation is that cities specialise in sectors, such as tradable services, where the content of tasks makes it difficult to automate stages of the production process and where business dynamism, negatively affected by demographic change, is a more solid driver of productivity growth. Finally, ageing seems to be associated with a redistribution of revenues away from workers and towards capital and firm owners.

JEL codes: J11, J24, R11

Keywords: productivity growth, ageing, regions, cities

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Executive Summary

OECD countries and their regions are ageing, with “ageing” referring to the increase in the share of older cohorts in the population. The share of individuals aged 65 or older increased from 19% to 23%, an increase of 21%, within only 14 years (2001-2014) across 1669 OECD TL3 regions. Despite this large shift, ageing receives less attention in OECD countries than other global megatrends, such as globalisation, automation or climate change. One explanation for the comparative lack of attention might be the belief that market mechanisms can attenuate or even reverse the adverse impact that ageing has on living standards. In part, this belief would be justified as recent US-based evidence suggests that an increase in the use of robots in production and automation of tasks would have the potential to fill the gap of a declining “prime age” workforce (Acemoglu and Restrepo, 2018^[1]). By raising the productivity of the workforce, automation would then help faster ageing regions and countries maintain their per capita income levels or even raise them.

The results presented in this paper question such complacency. By itself, ageing is expected to have a negative impact on per capita GDP (gross domestic product) growth given that it reduces the share of the potential workforce. In principle, this could be offset by increases in labour productivity (henceforth abbreviated as productivity), but for many regions, productivity growth required to offset such negative impact and therefore maintain per capita GDP levels constant is higher than the actual growth rates they recorded in the past years. On average, ageing reduced cumulative per capita GDP growth by 1.5 percentage points across TL2 regions in 19 OECD countries over the 2006-14 period. In about half of OECD regions, productivity growth was not sufficient to compensate for the negative effect of ageing on per capita GDP growth. In 85% of these regions, per capita GDP actually contracted. In the remaining regions, the average employment rate rose enough to prevent per capita GDP from falling, driven by an increase in the employment rate among older cohorts. Considering the annual rate of productivity growth during 2014-16 instead of the period that includes the financial crisis does not change the picture. If annual productivity growth during 2006-14 had been at the same level as in 2014-16, it still would not have been sufficient in one out of four regions to compensate for the negative effect of ageing on per capita GDP growth for the 2006-14 period.

One reason why regions struggle to raise productivity growth to compensate for ageing is that ageing itself can have an adverse impact on productivity growth. In OECD TL3 regions where ageing, defined as the growth rate in the old-to-young ratio (the ratio of the population above 50 to those that are 20-49 years old) exceeded the country average by 10 percentage points between 2001 and 2014, productivity growth was as a consequence 1.5 percentage points on average below the country average over the 2001-14 period. To put things into perspective, a 10 percentage points difference in the growth rate of the old-to-young ratio corresponds to roughly 1/4th of the difference between the fastest and slowest ageing region for the average country in the sample.

Urban TL3 regions are responsible for the negative impact of ageing on productivity growth. This might seem surprising as urban regions are, on average, younger than rural regions and ageing is progressing at a slower rate in urban regions (OECD, 2019^[2]). Differences in the sectoral composition across types of regions offer a potential explanation

for the stronger impact of ageing on productivity growth in cities. Ageing has no impact on productivity growth in the manufacturing sector, while it has a negative impact for tradable services, which are disproportionately located in cities.

Different channels can lead to the varying impact of ageing on productivity growth across sectors. The standardised nature of processes in manufacturing makes it easier to automate production or outsource more labour-intensive elements. Even in forestry or agriculture, the use of heavy machinery can significantly raise productivity of workers of all ages (OECD, 2018^[3]). In tradable services, automation has not (yet) progressed to the same degree as in manufacturing, since the prevalence of non-routine and interactive tasks has (so far) made it more difficult to automate or offshore these activities. Another channel leading to the differential impact of ageing on productivity growth across sectors is that knowledge-intensive services depend on a dynamic business environment with start-ups trying out new ideas and developing new momentum, at least more so than mature industries. Business dynamism, defined as the creation and closing of businesses relative to all firms in the region, is indeed lower in regions where the population is older. Furthermore, the decline in business dynamism associated with ageing is more rapid in urban regions than in rural ones.

Differences in the speed of ageing across regions has distributional consequences. Ageing reinforces the divide between the more productive – younger – regions and those lagging within a country. Transfers can compensate for the growing divide, with some of these transfers coming naturally through the (public) pension system. A relative increase in the retirees means an increase in pension flows towards the faster ageing regions. Transfers can help maintain living standards but are not very effective in unlocking a region's development potential (OECD, 2014^[4]). Growing economic divides are also not the only distributional consequence of ageing. Ageing is likely to also shift the distribution of production revenues between workers, capital and firm owners. This is the case, for example, if ageing triggers robots uptake, thus increasing the share of revenues accruing to robots owners. In contrast with the previous ones, these distributional consequences are intraregional. The labour share, which measures the percentage of total regional output that goes to workers, has declined more in fast-ageing regions. A region where the growth rate of the old-to-young ratio was 10 percentage points higher experienced, on average, a 2.5 percentage points faster decline in the labour share between 2001 and 2012.

Two sets of policies can be used to alleviate the consequences of ageing for living standards in regions. Policies can aim to broaden labour force participation or target productivity growth. Some examples of policies of the first kind are those attempting to reduce the gender participation gap or postponing the statutory minimum age for retirement. Both these examples can entail some trade-offs: for instance, it is necessary to ensure that an expansion in childcare facilities coverage is being pursued to boost female labour force participation, as opposed to alternative policies to reduce the gender participation gap that might have an adverse impact on birth rates, such as tax incentives (OECD, 2019^[5]). Similarly, pension reforms postponing the effective retirement age can inadvertently reduce average individual productivity if they are not coupled with initiatives promoting lifelong learning.

A full review of the policy options to stimulate productivity growth is beyond the scope of this work. Recent OECD publications give some guidance from different policy angles, ranging from framework conditions and structural reform packages (OECD, 2015^[6]), regional investment and leveraging local networks (OECD, 2018^[7]), to policies aimed at raising and retaining productivity of individual workers (OECD, 2018^[8]). In certain

circumstances, automation has the potential to maintain productivity of older workers and alleviate labour shortages in regions experiencing population decline (OECD, 2018^[3]). However, capital investment may not be sufficient and additional investment to improve the digital competencies of the elderly may be required. In line with the evidence presented in this paper on the negative impact of ageing on productivity growth across regions, further effort is however required of individual countries for them to be able to exploit the opportunities for productivity growth associated with automation.

1. Introduction

Most OECD countries are facing a continuous increase in the share of older cohorts in the population, i.e. they are “ageing”. The share of individuals aged 65 or older increased from 19% to 23%, an increase of 21%, within only 14 years across 1669 OECD TL3 regions (Figure 1.1).¹ Some of the trends underlying ageing are clearly positive, such as the rise in longevity. A person born in Japan in 2014 can expect to live almost 84 years, on average, up from 81.5 years in 2001.²

Ageing does not follow automatically from an increase in longevity. As long as birth rates increase sufficiently, longer lifespans and a young workforce can go hand in hand. However, birth rates have been falling across the OECD. In 41% of OECD regions, the birth rate was so low that population declined over the 2001-14 period.³ Moreover, a decline in birth rates compounds future ageing trends: a low birth rate today is likely to be matched by a low birth rate tomorrow owing to lower average individual fertility for an older population.

Ageing can have adverse economic consequences. For example, gains in life expectancy could be expected to be matched by an increase in the savings rate and a decline in the natural rate of interest, therefore making it harder for monetary policy to stabilise the economy (Bernanke, 2005_[9]). The picture on the fiscal side is equally challenging. An increasing share of retirees puts the sustainability of public finances in question. A growing

1 Regions (TL2 and TL3) are classified by the OECD into two territorial levels that reflect the administrative organisation of countries. The OECD’s large regions (TL2) represent the first administrative tier of subnational government, such as the Ontario region in Canada. OECD small (TL3) regions are contained within a TL2 region. For example, the TL2 region of Aquitaine in France encompasses five TL3 regions: Dordogne, Gironde, Landes, Lot-et-Garonne and Pyrénées-Atlantiques. In most cases, TL3 regions correspond to administrative regions, with the exception of Australia, Canada, Germany and the United States. TL3 regions have been classified as: predominantly urban, intermediate and predominantly rural based on the percentage of regional population living above certain thresholds of population densities.

2 Ageing can have other positive implications, such as the opportunity for certain regions to specialise in the “silver” economy. This local economic development choice is however not costless to implement, since it requires additional public investment, such as, for example, the strengthening of the health system of physical infrastructure on which the elderly especially depend.

3 It has been argued that there may be advantages related to the drop in birth rates and the associated population decline, such as for example the reduced pressure on the environment and natural resources. Their relevance is likely to be secondary when compared against the disadvantages.

share of public spending needs to be diverted towards health and pension expenditure and away from investment.^{4 5}

Compensatory measures, such as postponing the retirement age, can alleviate the pressure, but creates its own investment needs. As the working life extends, investment in older generations' skills, in particular digital competencies, and the necessity of committing to lifelong learning becomes increasingly important.

While most of the public discussion focuses on the national level, addressing ageing is even more pressing at the regional level given that ageing is progressing much more rapidly in some regions than in others (Figure 1.2). In the United Kingdom, for example, 18% of residents are 65 years or older, but the share is as low as 6% and as high as 28% across the country's TL3 regions. In the United States, the fastest ageing region has two times the share of elderly residents than the country average. Moreover, at a regional level, the outflow of working age residents towards places with more economic opportunities either within their own countries or abroad exacerbates the impact of low fertility rates and increased longevity on the average age.

Figure 1.1. The share of individuals aged 65 or older increased between 2001 and 2014

Note: Countries included are: AUS, AUT, CAN, CZE, DEU, DNK, ESP, FIN, FRA, GBR, HUN, IRE, ITA, JPN, KOR, NOR, NZL, POL, PRT, SVK, SVN, SWE, USA.

Source: OECD Regional Statistics (database), <http://dx.doi.org/10.1787/region-data-en>.

⁴ See the Handbook in Lee and Mason (2017_[66]) for a more detailed discussion of the macroeconomic effects of ageing.

⁵ The matter of ageing is gaining increasing attention among policy-makers. For instance, one of the three key research topics mentioned by the Australian Treasury is to achieve a better understanding of the effects of ageing on economic growth, with a special focus on the implications for fiscal policy, labour force participation, labour productivity and the natural rate of interest (see: <https://research.treasury.gov.au/research-topic/towards-a-better-understanding-of-the-effects-of-ageing-on-economic-growth/>).

Figure 1.2. Average ageing masks the severe pressures some regions are facing

Note: Data for TL3 regions in 2017, except for AUS, JPN, NZL, USA (2016); CAN (2012).

Source: OECD Regional Statistics (database), <http://dx.doi.org/10.1787/region-data-en>.

This paper provides an in-depth analysis of the potential for productivity growth to counter the expected negative impact of ageing on per capita gross domestic product (GDP). Older workers have lower labour force participation and employment rates. Ageing will therefore reduce the active workforce, unless employment rates adjust. In principle, policies succeeding at boosting labour productivity growth could effectively contain the negative impact of ageing on per capita GDP growth (IMF, 2016_[10]). This is because per capita GDP depends both on the share of workers in the total population and on their productivity. However, the potential for productivity growth to compensate for ageing might be impaired by a direct negative impact of ageing on productivity growth itself, as a number of cross-country studies finds. Complementing existing research, in a second step this paper therefore explores the link between ageing and productivity growth from a regional perspective.

The rate of productivity growth required to prevent per capita GDP from falling given the current trend of population ageing in OECD regions is, however, high. Cumulative per capita GDP growth would have been 1.5 percentage points higher in the absence of ageing on average across OECD regions between 2006 and 2014, while the actual average rate of productivity growth was 2.3% over the same period. In theory, the average region therefore managed to raise productivity more than enough to compensate for ageing. But this was not the case in all regions. In reality, productivity growth fell short of compensating for the negative impact of ageing on per capita GDP growth in almost half (49%) of OECD

regions, with the resulting implication that per capita GDP would have contracted in these regions unless compensated by other factors, such as an increase in the participation rate.

Considering the annual rate of productivity growth during 2014-16 instead of the one including the global financial crisis period does not change the picture. In one out of four regions, if annual productivity growth during 2006-14 had been the same as the level recorded in 2014-16, it would not have been sufficient to compensate for the negative effect of ageing on per capita GDP growth during 2006-14.

The pressure from ageing and therefore the need for productivity growth varies widely across regions. For example, in the absence of ageing, cumulative per capita GDP growth would have been 5.7 percentage points higher for the average Japanese region, while this number is as low as 1.9 percentage points for the average Western European region. However, while in Japan productivity growth was on average 6.4%, it was negative for the average Western European region. Productivity growth therefore failed to even partially compensate for the negative impact of ageing on per capita GDP growth in Western European regions.

The second contribution of this study is to ask why productivity growth failed to attenuate the impact of ageing on per capita GDP growth in many regions. It does so by considering the link between ageing, measured as the increase in the ratio of those 50 years or older in the region to those 20-49 year old, with productivity growth in itself.⁶ This link turns out to be negative and statistically significant, implying that productivity growth in faster ageing regions was lower than in slower ageing regions within a country. This negative link thus reinforcing the challenge of using productivity growth as a way to counteract the consequences of ageing for living standards.

Using lagged fertility rates as instruments for the growth rate in the old-to-young ratio, the results indicate that a region where ageing exceeds the country average by 10 percentage points was expected to grow cumulatively 1.5 percentage points slower than the country average in terms of labour productivity between 2001 and 2014. Taking a concrete example, the productivity growth of Madrid, the capital city of Spain, was 6.5%, about 3.6 percentage points lower than for the country as a whole. At the same time, the ratio of older residents to younger ones rose 10.4 percentage points more in Madrid than in Spain as a whole. The most conservative estimates suggest that about 50% of the growth gap are associated with the ageing population in the capital city. Similarly, ageing in Kyoto was 7 percentage points lower than the country average, while at the same time labour productivity growth exceeded the country average by 2.6 percentage points, implying that about 45% of higher growth experienced by Kyoto is due to more favourable demographic trends.

Productivity growth in a region or country might suffer from ageing for multiple reasons. Older workers have less incentive to invest into learning new skills and adapting to new technologies, which reduces their individual productivity. Younger people are also more likely to move across regions and jobs, so that ageing can lead to a more static labour

⁶ This measure differs from the widely used old-age dependency ratio, i.e., the ratio between the number of people of retirement age and the working age population. The rationale for combining older workers with those of retirement age is that the study aims to capture the extent of “ageing” in the workforce to which labour productivity refers.

market that is characterised by less experimentation, worse matching between jobs and workers and fewer improvements in worker productivity.

The negative impact of ageing on productivity growth is not necessarily only driven by compositional effects, since ageing can affect negatively productivity growth of all age groups (Maestas, Mullen and Powell, 2016^[11]). For example, population decline associated with ageing might trigger a reduction in firm entry, with negative consequences for creative destruction and the expansion of the productivity frontier (Hopenhayn, Neira and Singhanian, 2018^[12]). Furthermore, a workforce more imbalanced towards older cohorts changes the structure of teams and the assignment of tasks. More experienced workers might increasingly have to perform tasks that less experienced workers could have performed equally well, which means they lose time that would have normally been spent on more complex or managerial tasks, thus reducing their own productivity and the one of the team as a whole.

The average negative link between the increase in the average age and productivity growth, however, might hide the presence of balancing factors attenuating the impact of ageing on productivity growth in some places. Demographic pressure can facilitate innovation and the update of new technologies in firms to compensate for the shrinking “prime age” workforce, i.e., those that are 35-55 years old. For example the uptake of industrial robots and other tools for task automation can reduce the pressure of labour shortages and raise the productivity of the remaining workforce (Acemoglu and Restrepo, 2018^[11]).

A breakdown by regional typology shows that the impact of ageing on productivity growth is primarily driven by urban regions. Predominantly urban TL3 regions where the growth rate of the old-to-young ratio was 10 percentage points higher than the country average had, on average, 1.9 percentage points slower productivity growth than the country average. For intermediate regions the effect is 1.4 percentage points lower than for urban regions, whereas the estimate for predominantly rural regions is statistically insignificant. Differences in sectoral composition offer a potential explanation for the differential impact of ageing across region types. Productivity growth in the manufacturing sector is not found to differ systematically between regions ageing faster and those ageing more slowly. In contrast, the negative association between ageing and productivity growth is strongest in knowledge-intensive tradable services (Information and Communication Technologies and Finance and Insurance), which are predominantly located in cities.

A variety of channels can lead to the differential impact across sectors. Tradable services are characterised by a prevalence of non-routine and interactive tasks, which, in the past, have been harder to substitute for, while the standardised nature of processes in manufacturing has made it easier to automate production or outsource the most labour-intensive elements.

Another channel is that the process of “creative destruction” – the notion that less profitable (or productive) business ventures are abandoned in favour of more profitable (or productive) ones – is likely to matter more in sectors where technological progress is rapid. Dynamism, measured by the “churn” of businesses, i.e. the ratio of the total newly created and closed down business to total businesses in the region, is indeed lower in regions with an older workforce. This negative relationship is more pronounced in urban regions, in line with the argument that the sectors located in cities are more dependent on “creative destruction”.

Even if economic decline is averted through increased productivity growth, regions might see inclusiveness decrease. New forms of capital investment, such as investments into

artificial intelligence, are characterised by returns for the owners of the invested capital that increase in the size of the investment (OECD, 2017_[13]). A shift towards these forms of intangible capital can therefore lead to a redistribution of resources away from workers and towards entrepreneurs and capital owners. As a result, productivity improvements are reflected to a lesser extent into wage growth in fast-ageing regions. A useful concept for describing the responsiveness of real wage growth to labour productivity growth is the labour share, namely the fraction of total value added produced accruing to workers. The higher the labour share, the stronger the positive response of real wages to a labour productivity improvement. Already today, there is decline in the labour share in faster ageing regions. The growth rate in the labour share has been 2.5 percentage points lower over the 2001-11 period in regions where ageing was 10 percentage points faster, after controlling for correlated factors, such as the growth rate in capital intensity or average educational attainment.

This paper consists of four main sections. This introduction is followed by a short summary of related academic literature. Section three provides an overview of ageing trends across OECD regions, and Section four then links these trends with the required productivity growth to compensate for ageing. The fifth Section estimates whether and how much ageing affects regional productivity growth, while the sixth Section discusses the distributional impact in regional economies.

2. Related academic literature

Several studies have analysed the consequences of ageing for productivity growth (Feyrer, 2007^[14]; Aiyar, Ebeke and Shao, 2016^[15]; Liu and Westelius, 2016^[16]; Maestas, Mullen and Powell, 2016^[11]). In line with the findings in this paper, most of these studies find a negative association between the age structure of the population and aggregate productivity. An exception is Acemoglu and Restrepo (2018^[1]), who find a positive link. Their results indicate that countries where ageing has been faster are also characterised by a higher rate of technology adoption, which can therefore be considered the market response to increasing labour shortages and upward pressure on wages.

Ageing can have an impact on productivity growth for multiple reasons. One first line of explanations has to do with the changing composition of the workforce and the way in which individual productivity evolves during the life cycle of the worker. A large number of empirical studies have indeed investigated the relationship between individual productivity and age. Individual productivity rises with experience (Becker, 1993^[17]).⁷ Experience should rise over the life cycle but it is ultimately very difficult to measure. For this reason, several waves of economists have instead focused on the relationship between individual productivity and age, which is unlike experience a measurable attribute, and shown that productivity tends to increase up to a certain age and plateau thereafter (Aubert and Crépon, 2007^[18]), (van Ours and Stoeldraijer, 2011^[19]). Skirbekk (2004^[20]) further shows that whether productivity starts declining after a certain age heavily depends on the type of tasks involved in the workers job.

A second line of explanations goes beyond compositional effects in stressing how an ageing population can have detrimental effects for productivity growth of all workers. Maestas, Mullen and Powell (2016^[11]) show in particular how ageing has a negative impact on productivity growth of workers belonging to different age groups. In this sense, the relationship between age and productivity at the aggregate level does not need to be a rescaled version of the one observed at the individual level. For example, the relationship between the productivity and the age of workers is not identical to the one between the productivity of firms and the age structure of their employees (Grundke et al., 2017^[21]).

One reason for why the relationship between age and productivity at the aggregate level is not just a rescaled version of the one observed at the individual level is that there exist complementarities and spillovers across different elements of an integrated economic system, such as a firm or a region. The productivity of individual workers hinges in fact on the practices adopted by their managers (Bloom and Van Reenen, 2007^[22]), and on the one of the team to which they belong (Garicano, 2000^[23]). The negative consequences for firms

⁷ An imperfect empirical translation of the theory is the positive correlation between wages and the age of the worker (Mincer, 1974^[69]). The imperfectness stems from the fact that neither wages nor age perfectly capture worker productivity and experience, respectively. For instance, employers might pay less to young workers to induce them to exert effort, and compensate them for having done so later on during their career, in which case worker productivity would be constant and, yet, wages would be increasing with age (Lazear, 1979^[70]).

of being located in an ageing labour market are amplified by the existence of productivity spillovers at the local level (Ahrend, Lembcke and Schumann, 2017^[24]). For example, a shift towards an older workforce in a top performing firm can induce a productivity slowdown that trickles down onto the network of local suppliers serving such firm.

Alternatively, the relationship between age and productivity at the aggregate level differs from the one observed at the individual level by the way in which ageing affects the interaction and competition among individual firms. A few studies have dealt with the relationship between demographic shifts and firm dynamics, finding a close link between population decline and the decline in the start-up rate, the rise in product market concentration and the decline in the labour share (Karabarbounis and Neiman, 2014^[25]; Hopenhayn, Neira and Singhanian, 2018^[12]). Since population decline and ageing are interconnected, it is possible that ageing has itself played a role in shaping these aggregate trends.

Finally, differences in productivity growth between faster and slower ageing countries might be explained by differences in the rate of capital accumulation, as opposed to differences in the growth rate of average worker productivity.⁸ Several studies have considered the consequences of ageing for capital accumulation (Martins et al., 2005^[26]; Börsch-Supan, Ludwig and Winter, 2006^[27]; Geppert, Abiry and Abiry, 2016^[28]; Bárány, Coeurdacier and Guibaud, 2019^[29]). As life expectancy increases, the savings rate in the economy should rise as workers prepare for a longer retirement period and higher future costs of services. This increase in the capital-labour ratio reduces marginal product of capital, i.e. the returns for firms for additional investment, which determines the interest rate they are willing to pay. Demographic factors may play therefore an important role in the emergence of the global savings glut (Bernanke, 2005^[9]), and the associated low interest rate environment closer to its zero lower bound that undermines the stabilisation objective of monetary policy.

Overall, if the evidence on the nexus between the age structure of the population and labour productivity across countries appears to be scant, it is even scarcer at the regional level. An exception is a study by Zaninotto et al. (2018^[30]) who consider the relationship between productivity and the share of workers affected by the postponement of the effective retirement age imposed by the “Fornero reform” (2011) across Italian provinces. They also find a negative link between productivity and the share of old workers.

There are several reasons to depart from a national perspective and opt for a regional analysis. Firstly, the negative link between ageing and productivity growth could be stronger at the regional level, since capital and people are more mobile across regions within a country than across countries. Secondly, it could be that productivity growth is negatively affected by ageing only in the more productive regions, so that ageing would act as a force towards convergence. Alternatively, a negative link might only exist for the less productive regions. Ageing would therefore reinforce existing productivity gaps (OECD, 2018^[31]; McCann, 2016^[32]).

Within countries, public transfers might help overcome economic decline that individual regions face. Some of these transfers are natural as retirees start drawing on their (public)

⁸ See Lee (2016^[65]) for a review of the macroeconomic impact of ageing.

pensions. As output gaps continue to increase with ageing, the need for (additional) transfers will also continue increase. Sorting of young people into more productive (and higher cost) places and elderly into less expensive areas reinforces these divides. This risks an increasing dependence of some regions on transfers, risking the regions' capacity to leverage its growth potential and develop new economic opportunities.⁹ One sector that can emerge in ageing regions is the “silver” economy, i.e. goods and services that are targeted towards an ageing society. Some jobs associated with this trend will be in low-value added activities but new products will also emerge to support older people so that they can continue to live in their homes and retain autonomy in their daily life. New and redesign of housing that is adapted to elderly needs, ICT services that help with monitoring and facilitate access to services and other high-tech solutions are likely to be valuable complements to labour-intensive care activities (OECD, 2015_[33]).

⁹ See OECD (2014_[4]) for a discussion of the need to move beyond transfers in regional policy and rather focus on investments that unlock growth potential.

3. Demographic change across regions today and tomorrow

Ageing is progressing rapidly in OECD regions. Some regions already had a high share of elderly residents in 2001, some others are rapidly catching up (Figure 3.2 and Figure 3.3). These two figures show the level and the change in the “old-to-young ratio”, namely the ratio between the number of people aged 50 or more and the number of people aged between 20 and 49.¹⁰ In some regions, both of these factors coincide: for example, Spanish regions already had very high old-to-young ratios in 2001 and saw it growing further during 2001-14, or many of Japan’s regions that already had some of the highest old-to-young ratios in the OECD still recorded growth of 30% or higher. Other regions were “young” in 2001 but they experienced fast ageing during 2001-14, such as Korean regions or those located in the eastern *Länder* in Germany.

Ageing across the OECD is a gradual process as the “baby boomer” generation moves towards the later years in their work life and reach retirement age. The percentage of population aged 65 or older has increased by 3.5 percentage points across OECD TL3 regions with available data over the 2001-14 period, as the 20-49 age group contracted by more than 6 percentage points (Figure 3.1). The increase in the share of people of older working age, i.e. those 50 to 64 year old, increased roughly by 2.5 percentage points.

¹⁰ The traditional elderly dependency ratio (65+/20-64) and its growth are in the Annex (Figure A A.1 and Figure A A.2).

Figure 3.1. Workers in OECD TL3 regions are ageing steadily

Note: Countries included are: AUS, AUT, CAN, CZE, DEU, DNK, ESP, FIN, FRA, GBR, HUN, IRE, ITA, JPN, KOR, NOR, NZL, POL, PRT, SVK, SVN, SWE, USA.

Source: OECD Regional Statistics (database), <http://dx.doi.org/10.1787/region-data-en> (accessed on 05 February 2019).

Figure 3.2. The ratio of old (50+) to young (20-49) in 2001 across OECD TL3 regions

Source: OECD Regional Statistics (database), <http://dx.doi.org/10.1787/region-data-en> (accessed on 05 February 2019).

Figure 3.3. The growth rate in the ratio of old (50+) to young (20-49) during 2001-14 across OECD TL3 regions

Source: OECD Regional Statistics (database), <http://dx.doi.org/10.1787/region-data-en> (accessed on 05 February 2019).

Assessing future demographic changes is difficult and most projections are limited to the national level. Working with the European Commission's Joint Research Centre (JRC), the OECD has adapted one of the few subnational population projections that exist, the main scenario of Eurostat's "Europop2013" model (Eurostat, 2015^[34]).¹¹ The projections highlight a convergence in the age profiles of rural and intermediate regions, and a divergence for rural and intermediate regions with respect to urban ones (Figure 3.4). The rural-urban divide in terms of demographic profiles will grow by 2050, with urban regions expected to age slower than rural and intermediate regions. Diverging trends in birth rates certainly play a role, but economic migration is likely to be also important in countries where the productivity gap between slow and fast-ageing regions is increasing. Young individuals tend to move to urban regions because either cities can offer them better opportunities at the start of their careers, or they want to acquire therein an education and choose to settle there after they are finished with university.

Figure 3.4. The rural-urban divide in terms of demographic profiles will grow

Note: Population projections based on the Eurostat's "Europop 2013 scenario". Countries included are: AUT, CZE, DEU, DNK, ESP, FIN, FRA, GBR, HUN, IRE, ITA, NOR, POL, PRT, SWE, SVK, SVN. First year of projections: 2018.

Source: OECD Regional Statistics (database), <http://dx.doi.org/10.1787/region-data-en> (accessed on 05 February 2019) and Eurostat statistics on regional population projections (Eurostat, 2015^[34]).

¹¹ Europop2013 projects the current developments for fertility, mortality and net migration to 2080 at the national level and includes a component that projects demographic change at the regional level until 2050.

4. The need for productivity growth

Ageing affects per capita income in regions through different channels. The most direct channel is a decline in the labour force as labour force participation eventually declines with age and people reach retirement age. Due to the declining share of individuals of working age in the population, per capita gross domestic product (GDP) growth is expected to slow down or even turn into decline in regions ageing faster unless, of course, employment rates rise for older workers or the retirement age is postponed. However, per capita GDP depends both on the share of population involved in productive activities and on their productivity. Hence, enacting policies promoting productivity growth is a means to counteract the negative impact of ageing on per capita GDP growth due to the decline in the share of individuals of working age in the population.

The extent of productivity growth required to prevent per capita GDP from falling under the effect of population ageing varies across regions. In some regions, the need for productivity growth can be very demanding when compared to actual productivity growth and only the rise in average employment rates prevented ageing from having a negative impact on per capita GDP growth.¹²

However, raising employment rates has natural limits. Delaying the retirement age can lead to a decline in labour productivity as physical and cognitive skills change over the lifecycle and the incentive to invest into new skills diminishes as workers get closer to retirement. At the same time, policies favouring broader participation in the labour market across women can exacerbate the decline in birth rates if they are not complemented with measures improving child support and the ability to balance work and care activities. Therefore, there are natural limits to raising labour force participation, which strengthens the need to focus on productivity growth.

Estimating the need for productivity growth

The geographical units employed for this analysis are TL2 (Territorial Level 2) “large” regions that typically correspond to the first subnational level of government. There are a total of 363 large regions in the OECD. This classification is largely consistent with the Eurostat “NUTS 2” classification.

Per capita GDP can be broken down into the product of two components: labour productivity and the weighted average of age-specific employment rates. Following the formulation in Denton and Spencer (2017_[35]), a denotes age groups where $a = \{25 - 34, 35 - 44, 45 - 54, 55 - 64, 65+\}$, r a TL2 region, t the year, and GDP , POP , and E

¹² Policy measures have been focused on this dimension as well, e.g. in many countries pension reforms have postponed the retirement age to reflect gains in life expectancy. In some cases, pension reforms have gone as far as implementing actuarial neutrality as closely as possible: for instance, in Norway, as of 2011, the retirement age is a function of life expectancy, and even flexible retirement decisions must not violate the principle of actuarial neutrality (OECD, 2017_[64]). In addition to this, labour force participation among young women has increased steadily over the recent decades.

indicate real gross domestic product, population and employment, respectively. Then, (real) per capita GDP can be written as:

$$\frac{GDP_{r,t}}{POP_{r,t}} = \frac{GDP_{r,t}}{E_{r,t}} \sum_a \frac{E_{a,r,t}}{POP_{a,r,t}} \frac{POP_{a,r,t}}{POP_{r,t}} \quad (1)$$

An increase in the population share of individuals of retirement age (65+ year olds) reduces the average employment rate, as very few people in this age range actually work. The decline in the average employment rate then reduces per capita GDP. This intuition can be generalised and formalised using a first-order Taylor approximation. The negative impact of ageing on per capita GDP growth is then captured by:¹³

$$Ageing_{r,t} = \frac{\sum_a \frac{E_{a,r,2006}}{POP_{a,r,2006}} \left(\frac{POP_{a,r,2014}}{POP_{r,2014}} - \frac{POP_{a,r,2006}}{POP_{r,2006}} \right)}{\sum_a \frac{E_{a,r,2006}}{POP_{a,r,2006}} \frac{POP_{a,r,2006}}{POP_{r,2006}}} \quad (2)$$

Policies succeeding at boosting labour productivity growth could effectively contain the negative impact of ageing on per capita GDP growth (IMF, 2016_[10]). This is because per capita GDP not only depends on the share of workers in the total population, which declines under the effect of ageing, but also on their productivity.

The expression in (2) therefore also represents how much productivity growth would be required in a region to keep per capita GDP from declining due to ageing (assuming that employment rates remain constant at their 2006 value).¹⁴ For example, if ageing in a given region has caused per capita GDP growth to be one percentage point lower than it would have been without a change in the population distribution, then a 1 percentage point increase in labour productivity growth could have kept per capita GDP from decreasing.

The need for productivity growth is large compared to actual growth

Cumulative productivity growth between 2006 and 2014 that was required to offset the negative contribution of ageing on per capita GDP growth was about 1.5 percentage points for the average TL2 region. In some rapidly ageing regions the value was even higher, up to 5.7 percentage points for the average Japanese region (Figure 4.1). This need may seem low in light of the 8-year period, however, when benchmarked against actual productivity growth it is a challenging requirement. Labour productivity growth between 2006 and 2014 was 6.4% for the average Japanese region. The impact of ageing was compensated and per capita GDP prevented from falling, but at the expense of potential per capita GDP growth.

¹³ The breakdown keeps the participation rates fixed at the initial level to focus solely on the impact of ageing.

¹⁴ Annex shows the full decomposition of per capita GDP growth into labour productivity growth, the contribution of ageing, the contribution of changes in the employment rate, and the covariance between changes in population shares and employment rates across demographic groups.

Figure 4.1. Ageing reduced per capita GDP growth by 1.5 percentage points during 2006-14

Note: Countries included are: AUT, BEL, BGR, CZE, DEN, GRE, ESP, FIN, FRA, HUN, IRE, ITA, JPN, NLD, NOR, POL, PRT, SWE, SVK, USA. Eastern Europe countries are: BGR, CZE, HUN, POL and SVK. The age breakdown for the USA is: 25-49, 50-64, 65+. Units of observations are TL2 regions that have been aggregated into four large macroregions.

Source: OECD Regional Statistics (database), <http://dx.doi.org/10.1787/region-data-en> (accessed on 05 February 2019), EUROSTAT (EUROSTAT, 2019^[36]), Statistics Japan (Statistics Japan, 2019^[37]), American Community Survey (U.S. Census Bureau, 2019^[38]).

The impact of ageing on per capita GDP growth is negative everywhere with the exception of the average Eastern European region (Figure 4.1). In these regions, the share of population aged between 35 and 45 increased between 2006 and 2014 by more than one percentage point, unlike for Western European regions where, on average, it declined by 0.7 percentage points.

About half (51%) of OECD regions raised productivity sufficiently to offset the negative impact of ageing on per capita GDP growth during the 2006-14 period (Figure 4.3). In 85% of the 49% of remaining regions the result was a decline in per capita GDP as only 15% of regions saw employment rates rise enough to compensate for ageing (Figure 4.2).

The results are not very sensitive to the choice – which is guided by data availability considerations – of the financial crisis period as background for the calculations. Considering the annual rate of productivity growth during 2014-16 instead of the one during the financial crisis period does not change the picture. If annual productivity growth during 2006-14 had been the same as the level recorded in 2014-16, it still would not have been sufficient in one out of four regions to compensate for the negative effect of ageing on per capita GDP growth during 2006-14.

Figure 4.2. Increases in the employment rate did not compensate for ageing during the financial crisis

Note: For each year, the average contribution to per capita GDP growth across TL2 regions of changes in the employment rate, ageing, and their sum is displayed. Countries included are: AUT, BEL, BGR, CZE, DEN, GRE, ESP, FIN, FRA, HUN, IRE, ITA, JPN, NLD, NOR, POL, PRT, SWE, SVK, USA.

Source: OECD Regional Statistics (database), <http://dx.doi.org/10.1787/region-data-en> (accessed on 05 February 2019), EUROSTAT (EUROSTAT, 2019^[36]), Statistics Japan (Statistics Japan, 2019^[37]), American Community Survey (U.S. Census Bureau, 2019^[38]).

Differences in the severity with which the Great Recession hit Japanese and Western European regions can explain the different degree of compensation provided by productivity growth in the two sets of regions. In Japan, more than 50% of regions featured enough productivity growth to offset the negative impact of ageing. Per capita GDP declined in just 50% of the remaining regions, i.e. fewer than one in four regions experienced a decline in income levels. In contrast, in Western Europe, productivity growth in less than 50% of regions was high enough to compensate for ageing, and per capita GDP declined in more than 80% of the remaining ones.

The focus on maintaining income levels and preventing regions from declining in terms of per capita GDP might seem unambitious. Another benchmark that could be used is the pre-crisis growth in the different regions. The required productivity growth to retain pre-crisis per capita GDP growth levels during the 2006-14 period is significantly higher than the growth required to simply maintain income levels (Figure 4.3). Nearly 88% of TL2 regions were not able to reach the more ambitious productivity growth target and recorded strictly less productivity growth than the level required to maintain the same per capita GDP growth the region posted during the 2001-06 period.

Figure 4.3. In 49% of regions productivity growth fell short of compensating for ageing

Actual labour productivity growth vs. needed productivity growth (%)

Note: The observations correspond to TL2 regions. Per capita GDP growth depends on three components: labour productivity growth, demographic changes or ageing, and changes in the average employment rate. In this counterfactual, the average employment rate across demographic groups is assumed to be constant.

Source: OECD Regional Statistics (database), <http://dx.doi.org/10.1787/region-data-en> (accessed on 05 February 2019), EUROSTAT (EUROSTAT, 2019^[36]), Statistics Japan (Statistics Japan, 2019^[37]).

5. Ageing and labour productivity growth from a regional perspective

Ageing might have itself an impact on productivity growth in regions, which, if negative, can undermine the viability of a strategy relying on productivity growth as a way to counteract the consequences of ageing for living standards. Several channels provide a justification for the potential impact of ageing on productivity growth, some of which suggest a positive impact, some others a negative one. The analysis in the following section sheds light on which set of mechanisms dominates.

Estimating the impact of ageing on productivity

The geographical units employed for this analysis are TL3 (Territorial Level 3) “small” regions. There is a total of 1802 small regions in the OECD. Each TL3 region is contained in a TL2 region. In most cases, TL3 regions correspond to administrative regions. This classification is largely consistent with the Eurostat “NUTS 3” classification.

Ageing is measured as the growth rate in the ratio of old (aged 50 or more) to young workers (aged between 20 and 49). This measure has the advantage of capturing also ageing of the workforce and it has therefore a closer link with the evolution of the productivity of the workforce than the commonly used elderly dependency ratio (65+ as a percentage of the workign age population). In the regression analysis coming up in the next Section, changes in the old to young ratio in a given region can affect productivity growth both through the channel of an ageing workforce and through the channel of a growing share of retirees, potentially creating labour shortages that need to be compensated for, for instance, through technology adoption.

Formally,

$$Ageing_{r,2014-01} = \left(\frac{POP_{r,50+,2014}}{POP_{r,20-49,2014}} - \frac{POP_{r,50+,2001}}{POP_{r,20-49,2001}} \right) / \frac{POP_{r,50+,2001}}{POP_{r,20-49,2001}}$$

Following prior work at the country level (Acemoglu and Restrepo, 2018^[1]), the following regression describes the relationship between labour productivity growth and ageing:

$$\ln \left(\frac{GDP}{E} \right)_{r,2014} - \ln \left(\frac{GDP}{E} \right)_{r,2001} = \beta Ageing_{r,2014-01} + \gamma \ln \left(\frac{GDP}{E} \right)_{r,2001} + \alpha_c + e_r \quad (3)$$

Country fixed effects, α_c , control for country-level variation, while $\ln \left(\frac{GDP}{E} \right)_{r,2001}$ captures convergence (or divergence) among regions. The coefficient of interest, β , should be interpreted as a 1 percentage point faster ageing, i.e., increase in the old to young ratio, is associated with β percentage points higher (or lower if $\beta < 0$) productivity growth. Since the challenges posed by ageing in terms of productivity growth vary across sectors, the same specification is then used to describe the relationship between productivity growth and ageing at the sectoral level.

To address concerns of endogeneity in (3) the change in ageing can be instrumented. The concern is that the impact of ageing on productivity growth is confounded with the impact of several other factors that are not included in (3). If this were the case, the regression coefficient on ageing β , would be biased since it would pick up also the effect of these factors or “omitted variables”. Anticipated adverse economic development in a region might lead to an outflow of the most productive workers (“brain drain”) so that anticipated trends become a self-fulfilling prophecy. As these workers tend to be young or middle-aged it would also lead to faster ageing.

An instrumental variable approach offers a remedy to potential endogeneity issues. An instrument is a variable affecting ageing and correlated with productivity growth only through ageing. An instrumental variable might therefore necessary to isolate the causal impact on productivity growth of an exogenous increase in the old to young ratio, where exogenous means that it is not driven by third factors that are also relevant at shaping productivity growth.

Predetermined variables, such as historical fertility decisions, are valid instruments since they should be uncorrelated with contemporaneous abovementioned factors. Past fertility decisions affect the current age structure in a region as many people remain close to the area where they grew up, and at the same time current productivity growth should not be directly impacted by fertility decisions taken decades ago (other than through the current age structure in the region).

In the second part of the analysis, the specification in (3) is adjusted to explore any heterogeneity in the relationship between ageing and productivity growth based on the type of region. This is accomplished through the following specification, where $g \in \{Rural, Intermediate, Urban\}$ denotes the group each region belongs to:

$$\ln\left(\frac{GDP}{E}\right)_{r,2014} - \ln\left(\frac{GDP}{E}\right)_{r,2001} = \sum_g \left(\beta_g Ageing_{r,g,2001-14} + \gamma_g \ln\left(\frac{GDP}{E}\right)_{r,g,2001} + \delta_g \right) + \alpha_c + e_r \quad (4)$$

The correlation between productivity growth and ageing in urban, intermediate and rural regions is given by the coefficients β_{Urban} , $\beta_{Intermediate}$ and β_{Rural} , respectively. There are multiple reasons for why these coefficients might differ. A certain type of regions might be specialised in sectors where the impact of an ageing population on productivity growth is stronger. Alternatively, it could be that certain types of regions had been relying more than others on certain good practices to boost productivity, which however are becoming increasingly difficult to implement with an ageing workforce, such as an efficient organisation of production in teams or technology adoption. This paper provides an explanation for the heterogenous relationship between ageing and productivity growth across regions based on sectoral composition, for which data are easily available across regions and years.

Productivity growth is lower in regions ageing faster, especially in cities

The old-to-young ratio has increased for the median region by 25% between 2001 and 2014 (Table 5.1). Behind this aggregate statistic there is, however, a high degree of heterogeneity. The difference between median ageing in rural and urban regions is 6 percentage points and expected to widen according to projections (Figure 3.4). Economic migration of young workers away from less prosperous regions both within and across

countries will reinforce the different trends in the birth rate and increasingly shape the diverging demographic profiles across regions.

Table 5.1. Old-to-young ratio growth rates by regional typology (TL3), 2001-14

Group	5 th percentiles	median	95 th percentile	Number of regions
Predominantly rural	3.30	27.37	57.92	369
Intermediate	4.53	26.00	41.08	375
Predominantly urban	-0.76	21.41	39.69	382
All regions	1.95	25.16	49.54	1126

Note: TL3 regions are grouped into rural/intermediate/urban typology based on the OECD classification.

Source: OECD Regional Statistics (database), <http://dx.doi.org/10.1787/region-data-en> (accessed on 05 February 2019).

Regional productivity growth was, on average, uncorrelated with ageing (first column of Table 5.2). Cross-country differences are behind this result. Once country fixed effects are taken into account, ageing is strongly negatively correlated with productivity growth. Productivity in regions that are ageing 10 percentage points faster than the country average grows, on average, 1.6 percentage points slower than the national average (second column of Table 5.2).¹⁵

In Korean regions or many Eastern European regions, the old-to-young ratio has been growing substantially and productivity growth was fairly high. The growth was driven by substantial industrial growth and catching up and supported by the increased integration with local and global partners. The results without country fixed effects compare Korean regions with Hungarian, German or Portuguese regions. This omits structural differences between countries and the more straightforward comparison is between regions within the same country. Productivity growth was 1.6 percentage points lower than the country average in a Korean region where ageing exceeded the country average by 10 percentage points, which corresponds to the extent of ageing for the average region in the sample between 2001 and 2007.¹⁶

Stronger mobility of workers within countries rather than across countries offers a potential explanation for why productivity growth is negatively correlated with ageing across regions only when these belong to the same country. Out-migration of young workers from less

¹⁵ Existing cross-country studies have explored the role of ageing with respect to per capita GDP growth. One influential study find that per capita GDP growth is positively and statistically significantly associated with ageing across regions (Acemoglu and Restrepo, 2018^[1]). This is also evident in the regional analysis (first column of Table A A.2). A region experiencing 10 percentage points faster ageing is expected to have 1.9 percentage points higher per capita GDP growth. The positive correlation between ageing and per capita GDP growth, however, entirely disappears after controlling for variation driven by differences among countries (second column of Table A A.2).

¹⁶ The results do not depend on the chosen unit of disaggregation, since ageing features a negative and statistically significant correlation with productivity growth also across Metropolitan Areas (Table A A.3). The correlation is statistically significant only when population weights are used though, thus meaning that for highly populated Metropolitan Areas the relationship is significantly more negative than for less populated ones. Furthermore, the results are robust to the inclusion of Germany, although in this case the coefficient of interest is as low as one third in absolute value of the coefficient reported in the main regression (Table 5.2 and Table A A.1).

towards more productive regions in the same country is one reason for why regions whose productivity is growing less are also ageing faster. Mobility is a cause of concern when attempting to identify the causal impact of ageing on productivity growth, and an instrumental variable strategy is proposed in the remaining part of the analysis to take care of this concern.

Table 5.2. Ageing and labour productivity growth

VARIABLES	Labour productivity growth, 2001-14	
Growth old/young	0.02 (0.04)	-0.16*** (0.04)
Initial labour productivity	-0.34*** (0.02)	-0.10*** (0.02)
Observations	726	726
R-squared	0.54	0.76
Country FE	NO	YES

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Observations are TL3 regions in the following countries: AUT, CZE, DNK, ESP, FIN, FRA, GBR, HUN, IRE, ITA, JPN, KOR, NOR, POL, PRT, SWE, SVN, SVK.

Source: OECD Regional Statistics (database), <http://dx.doi.org/10.1787/region-data-en> (accessed on 05 February 2019).

To move beyond correlations and address potential endogeneity concerns, the share of 0-4 years old in 1981 and in 1991 is used as an instrument for ageing in the region. The validity of these instruments is justified based on the assumption that fertility decisions taken in 1981 and 1991 do not affect productivity growth between 2001 and 2014 except through their impact on population ageing. Given limitations on available data only a subset of regions can be included in the analysis. The relevant OLS estimate is reported alongside the instrumental variable (two-stage least squares) results.

The two-stage least squares results indicate that 10 percentage points faster ageing causes a 1.5 percentage points decline in productivity growth within countries. The impact is marginally lower compared to the OLS estimates (second column of Table 5.3), and the direction of the change suggests a downward bias, which is in line with what the majority of omitted variable examples would suggest.¹⁷ The fact that the estimated bias goes into the right direction lends credibility to the instrument(s) used and the corresponding estimates.¹⁸

¹⁷ A downward bias as in this case occurs when the omitted variable is positively (negatively) associated with ageing and negatively (positively) associated with productivity growth. Quality of institutions, presence of good universities or of an entrepreneurship-friendly policy environment are all examples.

¹⁸ See Table A A.7 for the first stage regression.

Table 5.3. Ageing and labour productivity growth: instrumental variable approach

VARIABLES	Labour productivity growth, 2001-14	
	OLS	2SLS
Growth old/young	-0.16*** (0.04)	-0.15* (0.08)
Initial labour productivity	-0.03 (0.02)	-0.03 (0.03)
Observations	461	461
R-squared	0.54	0.54
Country FE	YES	YES
F-test		62.81

Note: Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Countries included: ESP, FIN, FRA, GBR (only England and Wales), IRE, ITA, JPN, SWE. The set of instruments comprises of the share of 0-4 years old in 1981 and 1991.

Source: Labour productivity and population data: OECD Regional Statistics (database), <http://dx.doi.org/10.1787/region-data-en> (accessed on 05 February 2019). Historical population: Statistics of Finland (Statistics Finland, 2019^[39]), INSEE for France (INSEE, 2019^[40]); Central Statistics Office for Ireland (Central Statistics Office, 2019^[41]), ISTAT for Italy (ISTAT, 1982^[42]) and (ISTAT, 2019^[43]); Casweb for the United Kingdom and Wales (Casweb, 2019^[44]); INE for Spain (INE, 2019^[45]) and (INE, 2019^[46]); Population estimates 1920-2000 for Japan (Statistics Japan, 2019^[47]), Statistics of Sweden (Statistics Sweden, 2019^[48]).

Ageing is strongly negatively associated with productivity growth in predominantly urban and intermediate regions (second column of Table 5.4).¹⁹ In predominantly urban TL3 regions, 10 percentage points faster ageing is associated with a 1.9 percentage points decline in productivity growth relative to other regions within the country. Hence, a fast-ageing Polish city does not feature necessarily slower productivity growth than a slow-ageing Swedish city, but it does feature on average slower productivity growth than a slow-ageing Polish city.²⁰

The concentration of the impact of ageing in cities matters for at least two reasons. The first one is that the affected population is larger as more people live in cities, thus aggravating the aggregate repercussions of ageing. The second one is that ageing is expected to progress more slowly in urban areas compared to rural areas (Table 5.1). The heterogeneous speed of ageing across regions provides therefore an unseen benefit. The adverse impact on productivity growth due to the increase in the old-to-young ratio is milder in places where this ratio is going to increase the most.

¹⁹ TL3 regions have been classified as: predominantly urban, intermediate and predominantly rural based on the percentage of regional population living above certain thresholds of population densities, i.e. upon the share of urban dwellers.

²⁰ Result including Germany are reported in Table A A.6.

Table 5.4. Ageing and labour productivity growth: breakdown by regional typology

VARIABLES	Labour productivity growth, 2001-14	
Growth old/young (Rural)	0.18*** (0.07)	0.05 (0.06)
Growth old/young (Intermediate)	0.06 (0.07)	-0.14** (0.06)
Growth old/young (Urban)	0.05 (0.05)	-0.19*** (0.04)
Observations	697	697
R-squared	0.58	0.77
Country FE	NO	YES

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Observations are TL3 regions in the following countries: AUT, CZE, DNK, ESP, FIN, FRA, GBR, HUN, IRE, ITA, JPN, KOR, NOR, POL, PRT, SWE, SVN, SVK. The distinction between rural/intermediate/urban is based on the OECD classification. The coefficients on initial labour productivity for each group of regions are omitted from the displayed results. *Source:* OECD Regional Statistics (database), <http://dx.doi.org/10.1787/region-data-en> (accessed on 05 February 2019).

Differences in sectoral composition between rural and urban regions offer a potential explanation behind the disproportionate negative impact of ageing on productivity growth in cities. The sectors in which ageing has the most negative impact on productivity growth are tradable services, such as Information and Communication and Finance and Insurance (Figure 5.1), which tend to be disproportionately located in cities (Table A A.3).²¹

One potential channel behind the heterogeneous impact of ageing on productivity growth across sectors is the existence of compensating mechanisms – in particular capital investment – supporting productivity growth more easily in some sectors than in others. For instance, the adoption of robots in the wake of mounting labour shortages can be an effective tool for compensating for the negative consequences of ageing on productivity growth in the manufacturing sector. Existing research provides empirical evidence in support of the effectiveness of this compensating mechanism for the United States (Acemoglu and Restrepo, 2018^[1]). Unlike the study for the United States that focuses on per capita GDP and finds that automation can even overcompensate the impact of ageing and create positive stimulus to per capita GDP growth, the results for regional labour productivity suggest that the impact of ageing is, at best, absorbed through compensation mechanisms (Figure 5.1). Productivity in manufacturing or in hospitality and retail is less or not at all affected by ageing, in line with tasks performed by workers in these sectors having one of the highest risk of being replaceable by automation (OECD, 2018^[3]).

Automation of tasks for tradable services and the ability to source them from other places is still in its infancy. The preponderance of interactive tasks ties productivity growth in these sectors much more to the characteristics of the local workforce than in other sectors. Furthermore, the low content of routine tasks in more knowledge-intensive tradable services does not make automation a cost-efficient solution to implement in these sectors. Current trends suggest that new technologies will, however, reduce the barriers for remote interaction and facilitate the trading of services globally. This might lead to “Globalisation

²¹ IV results at the sectoral level are displayed in Table A A.5.

4.0” as the cost of (virtually) moving people between places is approaching zero (Baldwin, 2019^[49]).

Construction is another sector where technologies are not yet providing cost-effective complements to manual labour. The opportunities for automation, however, are rapidly growing. Autonomous mobile robots, for instance, are among the latest most innovative solutions in the field of robotics: the minimised reliance on external guidance (e.g., wires or sensors embedded on the floor) makes them apt at facing dynamic environments, such as construction or mining sites. Hence, the increasing rate of automation may soon start effectively counteracting the negative impact of ageing on productivity growth in these sectors as well.²²

Figure 5.1. Ageing and labour productivity growth by sector, 2001-14

Note: Each dot corresponds to the OLS coefficient on the growth rate of the old to young ratio in regression (3) estimated for labour productivity in a specific sector with country fixed effects. The line for each dot spans the 90% confidence interval of the corresponding coefficient given robust standard errors. Observations are TL3 regions in the following countries: CZE, DNK, FIN, FRA, GBR, HUN, IRE, ITA, PRT, SWE, SVN, SVK, 462 regions in total. For the breakdown into tradable vs. non-tradable see (OECD, 2018^[31]).

Source: OECD Regional Statistics (database), <http://dx.doi.org/10.1787/region-data-en> (accessed on 05 February 2019).

Another potential channel behind the heterogeneous impact of ageing on productivity growth across sectors is that knowledge-intensive sectors tend to rely more on business

²² See, for example, <https://www.abiresearch.com/press/construction-and-mining-represent-next-frontier-robotics-adoption-thanks-automation-technology-advances/> (accessed 27 March 2019).

dynamism than other ones. Business dynamism is measured by the sum of firm births and deaths over the total number of firms in a given period. Business dynamism underlies the process of “creative destruction”, which is the process through which new ideas are created that replace the old ones, thus pushing the innovation frontier further. In knowledge-intensive sectors, the process of “creative destruction” tends to be in the hands of young entrants as opposed to more mature sectors such as manufacturing.

Business dynamism is lower in older regions, captures by a higher ratio of old people in the region (50 years and older) compared young people (20-49 years). The decline in business dynamism associated with ageing is stronger among urban regions than it is among rural regions (Figure 5.2).²³ The concentration of knowledge-intensive sectors in urban regions might be the explanation for the stronger impact. Another reason might be that decline in dynamism is mainly driven by a lack of start-ups. Ageing is associated with population decline and population decline in turn has a negative contemporaneous impact on the start-up rate (Hopenhayn, Neira and Singhania, 2018_[12]). But other explanations are of course possible. The ambition of entrepreneurs might change with age. Evidence from the United States finds, on the one hand, that successful firms (in terms of growth) are, on average, founded by entrepreneurs in their mid-forties (Azoulay et al., 2018_[50]). On the other hand, the ambition of expanding a firm tends to decline in age and only a small fraction of early stage entrepreneurs is driven by the desire to bring a new idea to market (Hurst and Pugsley, 2011_[51]).

²³ The pattern holds qualitatively regardless of the year considered. Data on business dynamism at the TL3 level are available for a large set of countries starting in 2011.

Figure 5.2. Business dynamism is lower in “older” regions

Rate of business churn and ageing in TL3 regions, 2014

Note: The rate of business churn is the sum of total number of firm “births” and “deaths” as a ratio of the total number of firms in a given year. The old-to-young ratio is the total population 50 years or older divided by the population of 20-49 year olds. Both the rate of churn and the old-to-young ratio are demeaned within countries, i.e. a value of 5 for business churn indicates the region has churn rate that is 5 percentage points higher than the (unweighted) country average across TL3 regions.

Source: Calculations based on OECD Regional Statistics (database), <http://dx.doi.org/10.1787/region-data-en> (accessed on 05 February 2019).

An ageing region might experience lower productivity growth because an ageing population triggers a structural transformation where resources are reallocated towards less productive activities. An ageing society is in fact less dynamic, since young workers have a higher propensity to switch across jobs, occupations, industries and cities. To investigate whether the negative association between ageing and productivity growth is due to a structural transformation towards less productive sectors (e.g., healthcare), productivity growth is broken down into a component corresponding to average productivity growth across sectors and sectoral reallocation (Olley and Pakes, 1996_[52]).

Formally, denote with $\theta_{r,t,j}$ and $\omega_{r,t,j}$ labour productivity and the employment share in sector j , region r , and year t . Aggregate labour productivity in region r and year t equals $\theta_{r,t} = \sum_j \theta_{r,t,j} \omega_{r,t,j}$ and it can be rewritten as:

$$\theta_{r,t} = \overline{\theta_{r,t}} + \sum_j (\theta_{r,t,j} - \overline{\theta_{r,t}})(\omega_{r,t,j} - \overline{\omega_{r,t}}) = \overline{\theta_{r,t}} + OP \text{ Covariance}_{r,t} \quad (4)$$

where $\overline{\theta_{r,t}}$ and $\overline{\omega_{r,t}}$ denote respectively average labour productivity and employment share across sectors. The Olley and Pakes covariance ($OP \text{ Covariance}_{r,t}$) measures to what extent the resources in the region are well allocated. If the most productive sectors are on

average the ones with the largest employment shares, then the Olley and Pakes covariance is higher. Aggregate productivity growth depends both on the growth rate of average sectoral productivity and on the growth rate of the Olley and Pakes covariance.²⁴ Hence, sectoral reallocation, captured by an increase in the Olley and Pakes covariance, is a driver of productivity growth.

Regressing both components separately on ageing shows no negative statistically significant relationship between ageing and sectoral reallocation (Table 5.5). Hence, the hypothesis that ageing leads to a more “sclerotic” workforce, thus impairing the process of reallocation does not find the support of the data at least when it comes to reallocation across sectors. The sample, however, does become small, as data is missing for many regions. The result are standard errors that are relatively large and future work might find more evidence for hampered reallocation from ageing. What the results can support, despite the small sample size, is that fast-ageing regions grow less because average productivity growth across all sectors tends to be lower.

Table 5.5. Sectoral reallocation vs. average labour productivity growth

VARIABLES	OP Covariance Growth	Avg. Labour Productivity Growth	Labour Productivity Growth
Growth old/young	-0.25 (0.18)	-0.19* (0.11)	-0.08* (0.05)
Initial labour productivity	2.05 (1.72)	1.94** (0.92)	0.42 (0.57)
Observations	468	468	468
R-squared	0.15	0.20	0.69
Country FE	YES	YES	YES

Note: Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Countries included: CZE, DNK, FIN, FRA, GBR, HUN, IRE, ITA, PRT, SWE, SVN, SVK. The dependent variable is the growth rate of the Olley-Pakes covariance term (col.1), average labour productivity across sectors (col.2), total labour productivity (col.3). Outliers where the growth rate in either of the three variables exceeded 100% in absolute value have been dropped.

Source: OECD Regional Statistics (database), <http://dx.doi.org/10.1787/region-data-en> (accessed on 05 February 2019).

²⁴ The Olley and Pakes decomposition is an exact one when applied to productivity in levels, so that translating the decomposition to growth rates implies an error term. An exact dynamic decomposition can be found in Melitz and Polanec (2015_[68]).

6. Ageing and redistribution

Productivity is not just about efficiency in production, it also relates to the well-being of workers since it affects their earnings and the quality of their jobs (OECD, 2016^[53]). Fiscal transfers can of course buffer a lack of productivity growth or even decline associated with ageing. Fast-ageing regions should see their tax base decline and at the same time the pension share of public spending rise. In the absence of pure fiscal federalism, differences in the speed of ageing across regions naturally redistribute public resources away from slow-ageing towards fast-ageing regions. This does, however, have the potential to reinforce existing divides and can even challenge social cohesion within countries.

The shift in the relative distribution of economic gains between workers, firms and capital owner is another form of redistribution. Ageing affects average real wages through its impact on labour productivity, including through the capital/labour ratio, and on the responsiveness of real wage growth to labour productivity growth. Starting from the first one and based on the discussion in the previous section, ageing should put downward pressure on wages through its negative impact on labour productivity holding the capital-labour ratio constant.

Moving to the second channel, if population decline is associated with ageing and it is sufficiently strong, workers become scarcer and the relative wage, i.e., the average wage relative to the price of other factors in production, such as capital, rises. Furthermore, the capital/labour ratio can also increase in the absence of population decline if the increased savings of younger generations foreseeing their increased longevity outweigh the increased dissavings of older generations whose share in the population is growing.

The responsiveness of real wage growth to labour productivity growth is dictated by the evolution of the labour share, defined as:

$$\text{Labour Share}_{r,t} = \frac{P_{r,t}Y_{r,t}}{W_{r,t}L_{r,t}} \quad (5)$$

where $P_{r,t}Y_{r,t}$ is nominal GDP in region r and time t , and $W_{r,t}L_{r,t}$ is the total compensation of employees in region r and time t . The complement to the labour share is the sum between the share of revenues accruing to capital owners and the share accruing to the firm owners, or profits.

Taking the log difference of the expression in (5) yields:

$$-\Delta \ln(\text{Labour Share}_{r,t}) = \Delta \ln(Y_{r,t}/L_{r,t}) - \Delta \ln(W_{r,t}/P_{r,t}) \quad (6)$$

where Δ denotes the difference with respect to the previous year of the log of the variable in parenthesis. Hence, a decline in the labour share implies a larger positive gap between labour productivity and real wage growth. Given the steady decline in the labour share over the last decades in a large group of developed countries (Karabarbounis and Neiman, 2014^[25]), there is mounting evidence that real wage growth has become increasingly “decoupled” from labour productivity growth (OECD, 2018^[7]) and (Schwellnus et al., 2018^[54]). The decline in the labour share is neither explained by changes in capital intensity nor by changes in educational attainment, thus making the fading degree of competition in the economy and ensuing redistribution away from workers and towards firm owners a plausible candidate explanation (Elsby, Hobjin and Sahin, 2013^[55]).

Ageing features a negative and statistically significant association with the growth rate of the labour share. In TL2 regions with 10 percentage points faster ageing than the country average, the labour share declined 3.1 percentage points more (Table 6.2).²⁵ Part of the impact is due to differences in the growth rate of the capital/labour ratio or average educational attainment across regions. The relationship between ageing and the growth rate of the labour share is nevertheless still negative after controlling for correlated factors.²⁶ Hence, not only productivity growth is weaker, but also productivity improvements are reflected to a lesser extent into wage growth in fast-ageing regions.

The evidence on the negative link between ageing and changes in the labour share is compatible with the view that demographic change causes a slowdown in firm creation (Hopenhayn, Neira and Singhania, 2018^[12]), which itself is a necessary condition to keep incumbents under pressure and achieve the creative destruction that expands the productivity frontier. Declining pressure from firm entrants causes productivity growth to slow down and incumbents to appropriate increasingly large market shares, which causes markups to rise and the share of revenue accruing to workers to decline. Further research however is warranted to be able to establish a tighter link between demographic change and the fading degree of competition in the economy.

Table 6.1. Decline in the labour share and its determinants: summary statistics

Variable	5 th percentile	median	95 th percentile
Growth rate in labour share	-6.25	1.76	19.47
Growth rate of capital/labour ratio	-2.45	20.29	45.92
Growth rate share with tertiary education	16.66	36.77	61.83
Growth rate labour productivity	-9.84	5.11	14.83

Note: The variation is between 2001 and 2012. The units are 67 TL2 regions. Capital estimated as in (Derbyshire, Gardiner and Waights, 2011^[56]).

Source: OECD Regional Statistics (database), <http://dx.doi.org/10.1787/region-data-en> (accessed on 05 February 2019), EUROSTAT Regional Economic Accounts (EUROSTAT, 2019^[36]), Cambridge Econometrics (Cambridge Econometrics, 2019^[57]).

Table 6.2. Ageing and the decline in the labour share

VARIABLES	Growth rate in the labour share	
Growth old/young	-0.31*** (0.10)	-0.25** (0.11)
Growth capital/labour ratio		0.01 (0.06)
Growth share with tertiary education		0.12** (0.06)

²⁵ The analysis focuses on TL2 regions as estimates for the capital stock are required for the decomposition and data on investment (gross fixed capital formation) that is used to estimate capital stocks are not available at the TL3 level.

²⁶ Given the small number of regions the regressions do not include country fixed effects. The results are qualitative robust to the inclusion of fixed effects for the 6 countries with a statistically significant negative coefficient of -0.16.

Observations	67	67
R-squared	0.13	0.18

Note: Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The sample consists of TL2 regions with information on K/L ratio, share with tertiary education and labour share: AUT, DEU (only former West Germany), GRE, ESP, IRE, ITA.

Source: OECD Regional Statistics (database), <http://dx.doi.org/10.1787/region-data-en> (accessed on 05 February 2019), EUROSTAT Regional Economic Accounts (EUROSTAT, 2019^[36]), Cambridge Econometrics (Cambridge Econometrics, 2019^[57]).

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Annex A. Data and additional figures and tables

The unit of analysis in the section dedicated to the analysis of the productivity growth need are TL2 regions. The data on the employment rate by age group are sourced from the Regional Database of Eurostat for European countries, from the Labour Force Survey for Japan (Statistics Japan, 2019^[37]) and from the American Community Survey for the United States (U.S. Census Bureau, 2019^[38]). The data on real gross domestic product and population breakdown by age group are from the Regional Database of the OECD. Data are collected for 2006-16 (2006-2014 for the United States).

The unit of analysis in the section dedicated to the impact of ageing on productivity growth come from several sources. These data are recorded for the majority of European regions, Japan and South Korea for the 2001-2014 period. The data on gross value added (both aggregate and sectoral) are sourced from the OECD Regional Database, as well as the data on population composition.

The analysis also relies on 1981 and 1991 population data, which come from multiple sources: Statistics of Finland (Statistics Finland, 2019^[39]), INSEE for France (INSEE, 2019^[40]); Central Statistics Office for Ireland (Central Statistics Office, 2019^[41]), ISTAT for Italy (ISTAT, 1982^[42]) and (ISTAT, 2019^[43]); Casweb for the United Kingdom and Wales (Casweb, 2019^[44]); INE for Spain (INE, 2019^[45]) and (INE, 2019^[46]); Population estimates 1920-2000 for Japan (Statistics Japan, 2019^[47]), Statistics of Sweden (Statistics Sweden, 2019^[48]).

The analysis on the labour share finally draws on data from the European System of Accounts available on the EUROSTAT website.

Figure A A.1. The dependency ratio in 2001 across OECD TL3 regions

Source: OECD Regional Statistics (database), <http://dx.doi.org/10.1787/region-data-en> (accessed on 05 February 2019).

Figure A A.2. Growth rate in the dependency ratio during 2001-14 across OECD TL3 regions

Source: OECD Regional Statistics (database), <http://dx.doi.org/10.1787/region-data-en> (accessed on 05 February 2019).

Figure A A.3. Knowledge-intensive services locate in cities, manufacturing in rural areas

Note: The location quotient for sectoral employment is defined as $(E_{rs}/E_r)/(E_s/E)$ in 2014, where r is the region and s is the sector.

Source: Calculations based on OECD Regional Statistics (database), <http://dx.doi.org/10.1787/region-data-en>.

Figure A A.4. Ageing and labour productivity growth (leave-one country out estimates)

Note: Each dot correspond to the OLS coefficient on the growth rate of the old to young ratio in regression (3) estimated each time leaving out one country. The line for each dot spans the 90% confidence interval of the corresponding coefficient given robust standard errors.

Source: OECD Regional Statistics (database), <http://dx.doi.org/10.1787/region-data-en> (accessed on 05 February 2019).

Figure A A.5. Instrumental variable applied to sectoral productivity growth regressions

Note: Each dot correspond to the OLS (left panel) and the first IV strategy (right panel) coefficient on the growth rate of the old to young ratio in regression on labour productivity by sector. The line for each dot spans the 90% confidence interval of the corresponding coefficient. Countries included: FIN, FRA, GBR, IRE, ITA, SWE (366 TL3 regions in total). The set of instruments comprises of the share of 0-4 years old in 1981 and 1991.

Source: Labour productivity and population data: OECD Regional Statistics (database), <http://dx.doi.org/10.1787/region-data-en> (accessed on 05 February 2019). Historical population: Statistics of Finland (Statistics Finland, 2019^[39]), INSEE for France (INSEE, 2019^[40]); Central Statistics Office for Ireland (Central Statistics Office, 2019^[41]), ISTAT for Italy (ISTAT, 1982^[42]) and (ISTAT, 2019^[43]); Casweb for the United Kingdom and Wales (Casweb, 2019^[44]); Statistics of Sweden (Statistics Sweden, 2019^[48]).

Table A A.1. Ageing and labour productivity growth including Germany

VARIABLES	Labour productivity growth, 2001-14	
Growth old/young	-0.01 (0.02)	-0.06** (0.03)
Initial labour productivity	-0.33*** (0.01)	-0.14*** (0.02) (2.21)
Observations	1 126	1 126
R-squared	0.50	0.68
Country FE	NO	YES

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Observations are TL3 regions in the following countries: AUT, CZE, DEU, DNK, ESP, FIN, FRA, GBR, HUN, IRE, ITA, JPN, KOR, NOR, POL, PRT, SWE, SVN, SVK. A separate dummy is used for TL3 regions located in former West and East Germany.

Source: OECD Regional Statistics (database), <http://dx.doi.org/10.1787/region-data-en> (accessed on 05 February 2019).

Table A A.2. Ageing and per capita GDP growth

VARIABLES	GDP per capita growth, 2001-14	
Growth old/young	0.12** (0.05)	-0.06 (0.04)
Initial GDP per capita	-0.14*** (0.03)	0.06*** (0.02)
Observations	726	726
R-squared	0.16	0.74
Country FE	NO	YES

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Observations are TL3 regions in the following countries: AUT, CZE, DNK, ESP, FIN, FRA, GBR, HUN, IRE, ITA, JPN, KOR, NOR, POL, PRT, SWE, SVN, SVK.

Source: OECD Regional Statistics (database), <http://dx.doi.org/10.1787/region-data-en> (accessed on 05 February 2019).

Table A A.3. Ageing and labour productivity growth in Metropolitan Areas

VARIABLES	Labour productivity growth, 2001-14	
Growth old/young	-0.05 (0.07)	-0.26*** (0.10)
Initial labour productivity	-0.06*** (0.01)	-0.02 (0.02)
Observations	636	636
R-squared	0.54	0.52
Country/year FE	YES	YES
Population weights	NO	YES

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Observations are at the Metropolitan Areas/year level. Only countries with at least 15 Metropolitan Areas were included (DEU, FRA, GBR, ITA and POL) in order to consistently estimate the country/year fixed effects. Three medium-run changes are used: 2001-2004, 2004-2007, 2007-2010 and 2010-2013. In the second column, the observations are weighted according to the population in the end year.

Source: OECD Regional Statistics (database), <http://dx.doi.org/10.1787/region-data-en> (accessed on 05 February 2019).

Table A A.4. Ageing and labour productivity growth controlling for share with tertiary education

VARIABLES	Labour productivity growth, 2001-14	
	FRA, GBR, ITA, ESP	
Growth old/young	-0.26*** (0.04)	-0.24*** (0.04)
Growth share with tertiary education		-0.12*** (0.04)
Initial labour productivity	-0.03 (0.03)	-0.07** (0.03)
Observations	327	327
R-squared	0.49	0.50
Country FE	YES	YES
	CZE, FIN, HUN, JPN, KOR	
Growth old/young	-0.30*** (0.10)	-0.30*** (0.10)
Growth share with tertiary education		0.05 (0.07)
Initial labour productivity	-0.10** (0.04)	-0.10** (0.04)
Observations	116	116
R-squared	0.63	0.63
Country FE	YES	YES

Note: Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The share with tertiary education is defined as the fraction of population (ESP, FRA, GBR, ITA), or employment (CZE, FIN, HUN, JPN, KOR) with tertiary education.

Source: Labour productivity and population data: OECD Regional Statistics (database), <http://dx.doi.org/10.1787/region-data-en> (accessed on 05 February 2019). Share with tertiary education: OECD Regional Database for CZE, FIN, HUN, JPN, KOR (2000 and 2010 cross-sections), INSEE (INSEE, 2019^[58]), ISTAT (ISTAT, 2019^[59]), INE (INE, 2019^[60]), ONS (Office for National Statistics, 2019^[61]), EUROSTAT for 2001 data for ESP, FRA, GBR and ITA (EUROSTAT, 2019^[62]).

Table A A.5. Ageing and labour productivity growth controlling for tertiary education share: results for Germany only

VARIABLES	Labour productivity growth, 2001-14	
Growth old/young	0.07 (0.05)	0.09* (0.05)
Growth share with tertiary education		0.04 (0.04)
Initial labour productivity	-0.11*** (0.03)	-0.10*** (0.03)
Observations	383	383
R-squared	0.12	0.12

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. The share with tertiary education is defined as the fraction of employment with tertiary education. A dummy is included for TL3 regions located in former East Germany.

Source: Labour productivity and population data: OECD Regional Statistics (database), <http://dx.doi.org/10.1787/region-data-en> (accessed on 05 February 2019). Share with tertiary education: Bundersagentur für Arbeit for 2001 and GENESIS for 2011 (Statistisches Bundesamt, 2019_[63]).

Table A A.6. Ageing and labour productivity growth: heterogeneity by regional typology including Germany

VARIABLES	Labour productivity growth, 2001-14	
Growth old/young (Rural)	0.05 (0.04)	0.05 (0.04)
Growth old/young (Intermediate)	-0.00 (0.04)	-0.03 (0.04)
Growth old/young (Urban)	0.03 (0.04)	-0.11*** (0.04)
Observations	1,092	1,092
R-squared	0.53	0.69
Country FE	NO	YES

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Observations are TL3 regions in the following countries: AUT, CZE, DEU, DNK, ESP, FIN, FRA, GBR, HUN, IRE, ITA, JPN, KOR, NOR, POL, PRT, SWE, SVN, SVK. The distinction between rural/intermediate/urban is based on the OECD classification. A separate dummy is used for TL3 regions located in former West and East Germany. The coefficients on initial labour productivity for each group of regions are omitted from the displayed results.

Source: OECD Regional Statistics (database), <http://dx.doi.org/10.1787/region-data-en> (accessed on 05 February 2019).

Table A A.7. First stage of instrumental variable regression

VARIABLES	Growth old/young
Share 0-4 years old in 1981	7.504*** (0.670)
Share 0-4 years old in 1991	-7.074*** (0.732)
Initial labour productivity	-0.100*** (0.0246)
Observations	461

Note: Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Countries included: ESP, FIN, FRA, GBR (only England and Wales), IRE, ITA, JPN, SWE.

Source: Labour productivity and population data: OECD Regional Statistics (database), <http://dx.doi.org/10.1787/region-data-en> (accessed on 05 February 2019). Historical population: Statistics of Finland (Statistics Finland, 2019^[39]), INSEE for France (INSEE, 2019^[40]); Central Statistics Office for Ireland (Central Statistics Office, 2019^[41]), ISTAT for Italy (ISTAT, 1982^[42]) and (ISTAT, 2019^[43]); Casweb for the United Kingdom and Wales (Casweb, 2019^[44]); INE for Spain (INE, 2019^[45]) and (INE, 2019^[46]); Population estimates 1920-2000 for Japan (Statistics Japan, 2019^[47]), Statistics of Sweden (Statistics Sweden, 2019^[48]).

Annex B. Additional robustness checks

Some countries might be responsible for the magnitude and sign of the main coefficient of interest in (3). For this reason, this equation is first estimated each time leaving out one country (Figure A A.4). The correlation coefficient is equal to -0.16 when Germany is excluded from the sample, three times larger in absolute value than the correlation coefficient resulting from the exclusion in turn of the other countries. It follows that the coefficient of interest calculated only on German regions must be an outlier, which justifies the exclusion of Germany from the sample of countries considered.

There are two potential explanations behind the anomaly of the German case. The first one is that the manufacturing sector absorbs a large fraction of economic activity in Germany and this sector is the most likely to respond positively to demographic challenges through increased automation. The second one is that the speed of convergence in productivity between fast-ageing regions located in the eastern *Länder* and other German regions is higher than the one estimated on all countries due to the legacy of German division. In this sense, fast-ageing regions in Germany register high rates of productivity growth not because they are unaffected by ageing, but rather because they have a longer way to catch up with more productive regions in Germany compared to other countries.

The negative correlation between ageing and productivity growth is not driven by differences in educational attainment across cohorts. The negative association between ageing and productivity growth might be driven by a more subdued growth rate of average educational attainment in fast-ageing regions, since average educational attainment tends to be higher among younger cohorts. To explore this issues, countries have been grouped into two distinct groups depending on the source type for data on educational attainment. The regression in (3) is then run after the inclusion of the growth rate in the share of individuals with a tertiary education as control variable separately for: 1) France, Great Britain, Italy and Spain, for which data come from national censuses; 2) Czech Republic, Finland, Hungary, Japan and Korea, for which data come from labour force survey.²⁷ In conclusion, controlling for the growth rate in the share of individuals with a tertiary education hardly changes the sign and magnitude of the coefficient of interest).²⁸

²⁷ The inclusion of the growth rate in the share of individuals with a tertiary education as control variable should not be seen as an attempt to estimate a structural model of labour productivity. In order to do so, several additional variables are required, first above all capital intensity at the TL3 region level. Hence, the results should continue being interpreted as stemming from reduced form evidence.

²⁸ Results for Germany only are reported in Table A A.5.

Annex C. Derivations

An approximate expression for per capita GDP growth is:

$$\begin{aligned} & \frac{\frac{GDP_{r,t}}{POP_{r,t}} - \frac{GDP_{r,t-1}}{POP_{r,t-1}}}{\frac{GDP_{r,t-1}}{POP_{r,t-1}}} \\ &= \frac{\frac{GDP_{r,t}}{E_{r,t}} - \frac{GDP_{r,t-1}}{E_{r,t-1}}}{\frac{GDP_{r,t-1}}{E_{r,t-1}}} \\ &+ \frac{\sum_a \frac{E_{a,r,t}}{POP_{a,r,t}} \frac{POP_{a,r,t}}{POP_{r,t}} - \sum_a \frac{E_{a,r,t-1}}{POP_{a,r,t-1}} \frac{POP_{a,r,t-1}}{POP_{r,t-1}}}{\sum_a \frac{E_{a,r,t-1}}{POP_{a,r,t-1}} \frac{POP_{a,r,t-1}}{POP_{r,t-1}}} \end{aligned}$$

The first term on the right hand side of the equal sign is labour productivity growth, while the second term is the growth rate in the (weighted average of the age-specific) employment rate.

A useful decomposition for the second term is:

$$\begin{aligned} \hat{e}_{r,t} = & \frac{\sum_a \frac{E_{a,r,t-1}}{POP_{a,r,t-1}} \left(\frac{POP_{a,r,t}}{POP_{r,t}} - \frac{POP_{a,r,t-1}}{POP_{r,t-1}} \right)}{\sum_a \frac{E_{a,r,t-1}}{POP_{a,r,t-1}} \frac{POP_{a,r,t-1}}{POP_{r,t-1}}} + \frac{\sum_a \frac{POP_{a,r,t-1}}{POP_{r,t-1}} \left(\frac{E_{a,r,t}}{POP_{a,r,t}} - \frac{E_{a,r,t-1}}{POP_{a,r,t-1}} \right)}{\sum_a \frac{E_{a,r,t-1}}{POP_{a,r,t-1}} \frac{POP_{a,r,t-1}}{POP_{r,t-1}}} \\ & + \frac{\sum_a \left(\frac{E_{a,r,t}}{POP_{a,r,t}} - \frac{E_{a,r,t-1}}{POP_{a,r,t-1}} \right) \left(\frac{POP_{a,r,t}}{POP_{r,t}} - \frac{POP_{a,r,t-1}}{POP_{r,t-1}} \right)}{\sum_a \frac{E_{a,r,t-1}}{POP_{a,r,t-1}} \frac{POP_{a,r,t-1}}{POP_{r,t-1}}} \end{aligned}$$

The first component represents the contribution of ageing to per capita GDP growth evaluated at the initial age-specific employment rates: since during the sample period the composition of population shifted for most countries towards groups with zero or close to zero employment rates, this term tends to be negative on average.

The second component represents the contribution of changes in the employment rate to per capita GDP growth evaluated at the initial population shares. The employment rate might have decreased for some age groups over the sample period: if, however, it rose for other groups whose start-of-sample population share was higher, the contribution to per capita GDP growth of this component is also positive.

The third component is positive when on average the population share rose for groups that also experienced an increase in the employment rate.

Since the third component depends also on changes in the employment rate across age groups, the pure effect of ageing on per capita GDP is given by the first component only. This corresponds to the requirement for additional productivity growth in the main text, given the substitutability between this term and labour productivity growth in the approximate formula in the first equation.