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A STUDY OF TWENTY INDUSTRIALISED COUNTRIES**

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 Abstract

A shift in population distribution toward older ages is underway in industrialised countries throughout the world and will continue well into the future. We provide a framework for isolating the pure effects of population aging on per capita GDP, employ the framework in calculations for twenty OECD countries, and derive the rates of productivity growth required to offset those effects. We consider also some labour-related changes that might provide offsets, for comparison with productivity.

Keywords

> population aging, productivity, industrialised countries, projections

JEL Codes

> J1, J11, O4

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1. INTRODUCTION

The demographic shift toward older ages is underway in industrialised countries throughout the world and will continue well into the future. The economic effects, unmitigated, will be widespread and diverse. At a basic level they will be principally the result of a decline in the availability of labour supply in relation to an aging and increasingly dependent population, with a consequent reduction of real gross domestic product per capita. However there is the possibility that growth in aggregate productivity could provide an offset and we consider what rates of growth would be required for that to be effective. Given a set of forecasts of the population we describe a framework for isolating pure demographic effects on per capita gross domestic product (GDP) and calculating the required offsetting productivity growth rates. We show also how other possible offsets can be calculated within the same framework and we compare them with the productivity offset. Calculations within that framework are carried out for the top twenty OECD countries ranked in 2015 by GDP per capita (OECD, 2017c; two small countries, Luxembourg and Iceland, are omitted from the ranking).

In the 1930s there was much concern about the slowing rate of population growth and its consequences. Keynes (1937) for one confidently stated that population decline was in prospect:

"We know much more securely than we know almost any other social or economic factor relating to the future that, in the place of the steady and indeed steeply rising level of population which we have experienced for a great number of decades, we shall be faced in a very short time with a stationary or a declining level." (p 13)

He expressed grave concern about its economic consequences:

"the … result to prosperity of a change-over from an increasing to a declining population may be very disastrous" (p 14)

Such concern was echoed by Hansen (1939) who, in his presidential address to the American Economic Association, stated that since "we are in the midst of a drastic decline in the rate of population growth … it behooves us as economists to take cognizance of the significance of this revolutionary change in our economic life" (p 2) and then proceeded to introduce the concept of secular stagnation (p 4). Concerns with the declining rate of population growth and its economic implications dissipated abruptly with the rapid rise in fertility that started only a few years later. However they started to reappear in the 1970s and 1980s as the longer-run relationships between population change and economic performance began to receive more careful attention (see for example Denton and Spencer, 1973, IUSSP, 1978, Steinmann, 1984, Lee et al., 1988). It was becoming clear that the transition from the high fertility rates that followed World War II to persistently much lower rates in the 1960s and thereafter implied a fundamental and probably long-lasting shift in population age distribution in many industrialized countries. Demographers and others realized that the temporary postwar fertility "boom" would give rise first to an echo effect as the post-war children reached adulthood and had their own children (with much lower fertility), but then a pronounced aging effect as they moved on and into retirement and dependency in large numbers in the early decades of the 21st century, an effect strengthened by concurrent increases in life expectancy. Evidence of economic problems to come became more apparent as time passed and there was increasing

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concern about how to deal with rising health care, pension, and other costs associated with an older population in the face of a reduction in the labour force/dependency ratio, and hence in the level of output per capita that an economy could sustain.

Concern about the economic effects of population continues today, although without consensus about severity. Bloom, Canning, and Fink (2011) argue that "OECD countries are likely to see modest … declines in the rate of economic growth" but go on to suggest that "behavioral responses … and policy reforms … can mitigate the economic consequences of an older population" (p 2). The report of the National Research Council (2012), co-chaired by Ronald Lee, agrees: "… the impact of an aging population on overall living standards is likely to be modest" in the United States (pp 3-4). Maestas, Mullen, and Powell (2016) are less optimistic; they conclude, using US state-level data, that a "… 10% growth in the fraction of the population ages 60 and older decreases growth in GDP per capita by 5.5%" and that "two-thirds of the reduction is driven by a reduction in the rate of growth of … labor productivity" (p 4).

There is also a renewed concern about secular stagnation. The papers in Teulings and Baldwin (2014) summarize much of the debate; Summers (2014) focuses on the demand side, and the limitation of monetary policy in attaining full employment, while Gordon (2014) anticipates that the growth of productive potential itself will be reduced by four "headwind" barriers, one of which is demographic (the other three are education, inequality, and government debt; see also Summers, 2016, and Gordon, 2016). Acemoglu and Restrepo (2017), on the other hand, based on cross-country comparisons, find "no negative relationship between population aging and slower growth of GDP per capita" and conclude that "one possible explanation … is the endogenous response of technology" (p 10).

The present paper is intended as a contribution to this somewhat diverse literature by providing and employing a well-defined framework for quantifying the prospective supply-side effects of population aging on future GDP per capita over the period 2015-2045 in twenty industrialised countries, and particularly the potential for offsetting those effects through productivity growth were such growth to take place. Population aging may affect patterns of consumption as well – the ways in which GDP is used as the age distribution changes. But that is not our concern here. Our focus is the supply side of the economy in relation to the size of the population.

2. BACKGROUND: THE CURRENT OUTLOOK FOR POPULATION CHANGE

We consider first the demographic outlook for our twenty selected countries, in particular the prospective changes in age structure of their populations over the thirty-year period 2015 – 2045. The term "population aging" usually brings to mind only the increase in the share of older population. But aging, in the sense of rising average age, could as well come from a decline in the proportion of younger population. The more fundamental demographic issue from the point of view of effects on GDP per capita is the change in the proportion of dependents in the population, whether young or old, and the associated change in the working-age and labour force proportions. In the present state of the industrialised world population aging is mainly the result of an increased share of older population but it is of interest to consider initially both ends of the age spectrum. To that end we show, in Table 1, projected percentage shares of population 65 and over, projected shares of population under 20, and the two combined. We

refer to these age groups as the *dependent population*; some under 20 or over 65 are in fact in the labour force and some in the 20-65 range are not but the boundaries work well enough to approximate the changes in age structure of relevance here. (In one of our experiments below we consider the effects of possible increases in labour force participation rates of the 65-and-over population.) The shares in Table 1 are calculated from population projections provided by the United Nations (2017). The UN offers a number of alternative projections based on different assumptions; we have chosen the ones labelled "medium". (We examined the alternatives and determined that for our purposes a different choice would likely have little effect on the overall conclusions of the analysis to follow.)

Table 1 makes clear just how widespread is the prospective shift in age structure. Starting at the old end, the proportion 65 and over increases in every one of the twenty countries between 2015 and 2025, and again between 2025 and 2035; nineteen countries show a further increase between 2035 and 2045. Taking the thirty-year period as a whole, the (unweighted) average proportion increases by 9.2 percentage points (18.1 to 27.3); the largest increase is 20.2 percentage points (Korea), the smallest is 3.8 (Sweden). There are some offsets at the other end of the age spectrum; a few countries show increases in the proportion under 20. However most show declines and the average under-20 proportion falls by 1.8 percentage points. Overall the changes at the young end of the spectrum are dominated by changes at the old end. The dependent population share, as we call it – the two groups combined – increases generally in the same manner as the 65-and-over share: every country shows an increase in the first two decades and all but three in the third; every country shows an increase over the whole of the 30-year span. The average dependent share increases from 40.3 percent in 2015 to 47.8 in 2045.

3. A FRAMEWORK FOR ANALYSIS

The initial variables of interest are symbolized as follows: Y for (real) GDP, N for population, L for labour force, E for employed labour force, U for unemployed labour force, H for average hours worked, and $\overline{H}$ for average *efficient* hours worked (definition to follow). Subscripts t for time period and x for age-sex group (hereafter ASG) are attached as needed; variables with no x subscript are aggregates over the entire population or derived aggregate ratios. Productivity is symbolized as p and defined as GDP/$\overline{H}$.

The productivity variable merits special comment. Although conventionally labeled (or mislabeled) "labour productivity" it has of course a more general interpretation. It can be viewed as determined by several broadly defined influences: the quality of labour (education, training, experience); the capital/labour ratio (capital itself consisting of many types); the ratio of other inputs to labour input (land, raw or processed materials); the state of technology, in its many aspects; the rate of dissemination of new technology among firms and industries; possible returns to the scale of production; and the industrial distribution of aggregate labour (overall productivity can increase by a reallocation from lower to higher productivity industries). All of these possible determinants should be kept in mind when we talk about increases in p below as a possible offset to the effects of population aging. One usually thinks of advances in technology as responsible for productivity growth but any or all of the other influences noted could be in play, alone or in conjunction with changing technology. (The determinants of labour productivity are most often implicit in production theory but reformulation of a production equation can place output per unit of labour on the left side and make the relationships explicit.)

Now consider the following identity:

(1) $y = p \sum_x r_x e_x h_x q_x n_x$

where $y = Y/N$; $r_x = L_x/N_x$; $e_x = E_x/L_x$; $h_x = H_x/E_x$, $q_x = \bar{H}_x/H_x$, and $n_x = N_x/N$. In words, per capita GDP is equal to the product of the labour force participation rate, the fraction of the labour force employed, average hours worked, the work efficiency ratio (as we shall call it), and the population share, summed over all ASGs and multiplied by the productivity ratio. (Note for later use that $e_x = 1 - u_x$ where $u_x = U_x/L_x$ is the unemployment rate for ASG x.)

Our concern is the disadvantageous effect of prospective demographic change on GDP per capita. As discussed above, the most important and widely recognized effect is the increase in the proportion of older dependents as a population ages and the consequent reduction of the proportion in the labour force. But there is another possible effect of interest, the shift in age distribution within the labour force itself. A question that one could ask is whether an hour worked by a new young labour force member should be treated as the equivalent of an hour worked by someone more experienced, or whether an hour worked by an older worker near retirement age should be considered as productive as one contributed by a middle-aged worker. Younger workers may lack experience but their more recent education and training may give them an advantage in the application of newer knowledge and techniques. Older workers, more experienced as they are, may never the less lack that advantage. We know of no data that would allow us to do definitive calculations to answer questions of this kind but we can ask whether differences, if they do exist to any substantial degree, could matter. Could the effects of population aging on GDP per capita differ significantly if we were able to take differences in the age distribution of the labour force into account? We have allowed for the possibility that such differences might in fact matter by distinguishing between H and $\bar{H}$ and incorporating ASG-specific work efficiency ratios in equation (1): an hour of $\bar{H}$ is of the same productive quality, whatever the age or sex of the worker, but that need not be true of H. Aggregate productivity can be written as $p = Y/\bar{H} = Y/\sum \bar{H}_x = Y/\sum q_x H_x$. In the initial calculations below we simply accept the absence of data and set $q_x = 1$ for all x. In some subsequent ones though we experiment with alternative assumptions about the q_x values to see whether different assumptions might mitigate or augment the calculated effects of population aging.

4. AN INDEX OF PURE DEMOGRAPHIC EFFECTS ON GDP PER CAPITA

We define pure demographic effects as the changes that occur to GDP per capita when only the age-sex distribution of the population is allowed to vary. With that in mind we now attach time subscripts to the variables, choose $t = 0$ as a base year (we will be working with annual data), adapt equation (1), and write

(2) $y_t = p_t \sum_x a_{xt} n_{xt}$

and then, setting $a_{xt} = a_{x0}$, write

(3) $\bar{y}_t = \bar{p}_t \left(\sum_x a_{x0} n_{xt} \right) / \left(\sum_x a_{x0} n_{x0} \right) = \bar{p}_t \bar{d}_t$

where $a_{xt} = r_{xt}e_{xt}h_{xt}q_{xt}$; $\bar{p}_t = p_t/p_0$ is an index of overall productivity; $\bar{d}_t$ is an index of pure demographic effects, and $\bar{y}_t = y_t/y_0$ is an index of per capita GDP, conditional on $\bar{p}_t$ and $\bar{d}_t$. Now replace $\bar{p}_t$ with $\bar{p}_0 = 1$ so that $\bar{y}_t = \bar{d}_t$. The value of $\bar{d}_t$ then answers the question, what would the index of per capita GDP be in year t if the productivity level and all of the components of a were to remain constant at their year 0 levels and only the values of n were to change?

In the world of price indexing $\bar{d}_t$ would be called a Laspeyres or base-weighted index: x could stand for type of commodity, n could be replaced by price, and a could be replaced by quantity purchased. Holding quantities purchased constant for indexing purposes does not imply that there would be no *behavioural* response of quantities to price changes; it is simply for the purpose of isolating one type of change from the other. Similarly, holding the a_x values constant while allowing the n_x values to change does not imply that there would be no behavioural responses of participation rates, employment rates, or average hours to changes in population structure. The aim is simply to identify the pure or direct effects of population changes on GDP per capita.

5. PRODUCTIVITY GROWTH AS A POSSIBLE OFFSET

In practice $\bar{d}_t$, calculated from predicted population numbers, will generally be less than 1 for $t > 0$, as we will show below, and may be regarded as representing future downward effects of population aging on GDP per capita. We can then ask, what level of productivity would be needed to offset the effects of aging? To put it more concretely, what value of $\bar{p}_t$ would be required to yield $\bar{y}_t = k_t$ where k_t is the target level of GDP per capita for year t? Let us call the required level of the productivity index $\hat{p}_t$, which is calculated as $\hat{p}_t = k_t/\bar{d}_t$. If the goal is to maintain the level of GDP per capita that prevailed in the base year then $k_t = 1$; if some annual rate of increase π in GDP per capita is the goal then $k_t = (1 + \pi)^t$. Needless to say, setting k_t to some value as a goal and calculating $\hat{p}_t$ accordingly is not to say that there is some button that could be pressed to achieve that goal; it is simply what would be required to offset aging effects, whether achievable or not.

5. OTHER POSSIBLE OFFSETS

Our principal focus is productivity growth as an offset to future population aging but equation (3) suggests the possibility of alternatives: $r, e,$ or h could vary. To explore the effects of increased labour force participation rates, for example, we can redefine a as a' and rewrite equation (2) as

(4) $y_t = p_0 \sum_x a'_{xt} r_{xt} n_{xt}$

where $a'_{xt} = e_{xt}h_{xt}q_{xt}$. We can then make corresponding changes to equation (3) and write

(5) $\bar{y}_t = \bar{p}_0(\sum_x a'_{x0}r_{xt}n_{xt})/(\sum_x a'_{x0}r_{x0}n_{x0}) = \bar{p}_0\bar{g}_t = \bar{g}_t$

$\bar{g}_t$ is a combined index of demographic and participation rate effects and $\bar{p}_0$ is set to 1 since participation rate changes now replace productivity change in the exploratory calculation. Changes in the employment ratio and hours worked can be handled in a similar fashion, redefining $\bar{g}_t$ accordingly. We investigate below how effective changes in all three of these variables might be as an alternative to productivity growth in offsetting the future effects of population aging.

The work efficiency ratios are not observable in any year, including the base year $t = 0$, and they are thus just a matter of assumption from the beginning. However the effects of alternative assumptions about them can be investigated by resetting the q_{x0} components of a_{x0} in equation (3) and recalculating $\bar{d}_t$. Were we to make alternative assumptions about the q_{x0} values would that increase or decrease the effects of prospective population aging and require a significantly different rate of productivity growth to provide an offset?

6. DATA AND DERIVED VARIABLES

The set of population projections that we use for our twenty countries is the medium variant of the several sets published by the United Nations (2017), as noted above. (The methodology is described in United Nations, 2015.) With one necessary and limited exception, observations for all other variables (required for the base year 2015) are calculated using OECD data (2017a,b,d) based on labour force survey information reported by member countries. The calculations of r, e, and h are thus based on OECD data. (Note that participation rates (r) are calculated by us using UN total population numbers by age/sex group as denominators rather than survey population numbers, which may differ among countries because of differences in survey coverage.)

Survey coverage and definitions do vary to some extent among member countries; the OECD compiles and publishes the data for individual countries in as consistent a form as it can but complete uniformity is not possible. That implies some distortion in intercountry comparisons in our calculations. The degree of distortion is almost certainly small though in comparison with the demographic changes that drive the results reported below. Aside from survey and coverage differences there are detailed reporting differences among countries that had to be dealt with, especially with regard to grouping at the older end of the age scale but of other kinds as well. We have made adjustments where necessary to allow for these differences. (See Appendix for further discussion and details of the data and associated calculations.)

7. FUTURE GDP PER CAPITA WHEN THERE IS NO OFFSET TO POPULATION AGING

We apply equation (3) now, with $\bar{p}_t = \bar{p}_0 = 1$, to calculate $\bar{d}_t$ indexes, representing the pure effects of population aging on GDP per capita over three decades starting from 2015. The results are provided in Table 2.

The first and most conspicuous result to be observed in Table 2 is the commonality of declines. All twenty countries show a drop in the GDP per capita index in each of the three decades. The average decline between 2015 and 2045, all countries combined, is 11.2 percent. There is considerable diversity in the extent of the declines but no doubt about their prevalence. The effect of population aging on GDP per capita among industrialized countries is clearly widespread, as is population aging itself.

Looking further at the table we note that nine countries show a decline in GDP per capita of as much as 5 percent or more in the first decade and ten show a decline of 10 percent or more over the thirty-year period as a whole (one country, Spain, shows a decline of 22.1 percent).

8. PRODUCTIVITY GROWTH RATES THAT WOULD BE REQUIRED TO OFFSET POPULATION AGING

As noted earlier, if we assume a target annual GDP per capita growth rate π the level of productivity required by year t consistent with that rate is $\hat{p}_t = (1 + \pi)^t / \bar{d}_t$. We consider two possibilities in application: $\pi = 0$ (the base year level of GDP per capita is maintained) and $\pi = .01$ (GDP per capita increases by one percent per year). Table 3 shows results for $\hat{p}_t$ when $\pi = 0$, in each of the three decades from 2015 to 2045, in terms of both index levels and rates of growth. Table 4 shows results when $\pi = .01$. The levels of $\hat{p}_t$ when $\pi = 0$ and the corresponding levels of $\bar{d}_t$ are plotted in Figure 1 for the ten countries with the largest populations in 2015.

To maintain the 2015 level of GDP per capita would require positive increases in productivity in every one of the twenty countries over the whole of the period 2015-3045, and in every component decade. (The decade rates shown in Table 3 are all positive; a few of the corresponding annual rates display as zero because of rounding.) The average decade percentage rates of productivity growth for all countries combined are 5.0, 5.0, and 2.6, consecutively, in the three decades, and 4.2 for the 30-year period. There is considerable variation though, both across countries and over the decades: the highest decade rate of productivity increase required to stop GDP per capita from declining is 9.3 percent in Italy in 2025-2035; the lowest rate is 0.1 percent in New Zealand and Sweden in 2035-2045. For the period 2015-2045 as a whole the rates range from 1.7 percent per decade (New Zealand) to 8.7 percent (Spain).

If sights are set higher and the target rate of growth of GDP per capita is pegged at 1 percent per year, 10.5 percent per decade, the required productivity growth rates are of course much greater. The 2015-2045 growth rate is 15.1 percent per decade, on average, across the twenty countries. The lowest 2015-2045 rate is 12.3 percent per decade (New Zealand), the highest is 20.1 percent (Spain).

An obvious question is how the projected requirements for productivity growth rates compare with actual historical rates. We provide in Table 5 a comparison of the rates required to achieve 1 percent growth in GDP per capita over the full thirty-year projection period and over the first ten years of that period, 2015-2045 and 2015-2025, with rates in the most recent historical periods of corresponding length, 1985-2015 and 2005-2015.

Historically, productivity growth rates in the decade 2005-2015 were below the actual thirty-year averages in most countries, well below in many; only two countries had rates that were higher – slightly higher in Ireland (but almost the same) and Spain. The all-countries average for 2005-2015 was just a little over half the thirty-year average; productivity growth had slowed conspicuously by the early years of this century. Looking ahead, the projected required rates for 2015-2025 are higher than the 2005-2015 actual rates, and generally much higher: the all-countries average of required rates for 2015-2025 is 16.0 percent per decade, the 2005-2015 average of actual rates is 10.9. In only two countries is the reverse true, Ireland and Korea (for those two the projected rates are very much lower than the 2005-2015 actual rates). Overall, achieving 1 percent growth in GDP per capita would require a reversal of the historical decline in productivity growth in most industrialised countries.

A slightly more optimistic view perhaps (if we may put that way) is supported by comparison of the projected required rates with historical thirty-year rates, rather than with the more recent ones. The

all-countries average rate of productivity growth per decade in 1985-2015 was 19.9 percent; the all-countries average projected rates are lower than that – 16.0 for 2015-2025, 15.1 for 2015-2045. Among individual countries, thirteen have projected rates for 2015-2025 that are lower than the historical thirty-year rates, fourteen have projected rates for 2015-2045 that are lower than those rates. (All of these calculations exclude Austria, for which a 1985-2015 productivity growth rate was not available.) How one views the possibilities for annual rates of 1 percent productivity growth in the future thus may depend to some extent on one's choice of historical benchmarks and what one thinks is the likelihood of a reversal of the observed general downward trend.

9. COULD OTHER CHANGES PROVIDE SIGNIFICANT OFFSETS TO POPULATION AGING?

Now consider alternatives to productivity growth as offset possibilities, in particular changes in labour force participation rates (r), unemployment rates ($u = 1 - e$), and average hours worked (h). Taking r as an example, as in equation (5), $\bar{g}_t$ now represents the combined effect of altered participation rates and population change. To get some idea of how higher participation rates, representing deferred retirement, might offset population aging we increase r by half for all age groups over 65 by the year 2025, leaving the rates constant thereafter. The results are shown in Table 6. Alternatively we replace r with e in equation (5) - we lower all unemployment rates by one-third by 2025 (again constant thereafter), and then reset $e = 1 - u$ accordingly; the results of this are shown in Table 7. Next we replace r with h and reset the latter for all age groups at 5 percent above the initial levels by 2025; results are in Table 8. Finally we make a combined substitution to incorporate all three changes simultaneously in equation (5); results are in Table 9. The changes we have chosen to make are arbitrary but substantial. We could have introduced further changes in the second and third decades of the projection period but a feature of these kinds of change is that they are effectively bounded, realistically if not absolutely. There are practical limits to how much one could expect hours of work or the participation rates of older people to increase, or the rates of unemployment to decrease. They are unlike productivity in that regard, which as far as we can tell at the moment can increase indefinitely, whether slowly or rapidly. (Longer-term effects on productivity of environmental degradation or natural resource depletion are another matter.)

Increasing participation rates by half for older age groups has some effects, mostly in the first decade, and generally modest. With only population change the average index of GDP per capita is 95.3 in 2025 and 88.8 by 2045; incorporating the participation changes as well raises the average index level to 97.0 in 2025 and to 90.7 in 2045. Decreasing all unemployment rates by a third has similarly rather small effects: average index levels are 97.3 in 2025, 90.7 in 2045. Increasing hours of work by 5 percent has notably greater effects, yielding average index levels of 100.1 and 93.3; the decline in GDP per capita is completely offset in 11 of the 20 countries in 2025 by increasing average hours. There are no cases of complete offset in 2035 or 2045; GDP per capita is still below its initial level in all countries in those years. Never the less, the effects are substantial. To put the magnitude of the change in average hours in perspective, 40 hours a week would become 42 with a 5 percent increase; an 8 hour day would be increased by 24 minutes. (That is not a comment on the feasibility or desirability of such an increase, just a matter of arithmetic perspective.)

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The final experiment with these changes involves hypothetically implementing them all at once, as in Table 9. The results of doing that is to virtually eliminate the effects of population aging in 2025 and, if not eliminate them in 2035 and 2045, at least reduce them drastically. The increase in average hours of work is the dominant contributor to these collective effects.

There is an important consideration to keep mind in judging the foregoing results. The calculations underlying Tables 6 - 9 are based on equation (5), which assumes that the index of productivity remains at its base period level; other variables change but the productivity index remains at $\bar{p}_0 = 1$. The implication is that all of the determinants of productivity are unaffected when participation rates, unemployment rates, or average hours of work are changed. That is to say, the amount of capital per unit of labour remains the same, the scale of production, the distribution of industrial output between high and low productivity industries, and so on (see section 3). That is a strong assumption. It would have to be accepted in order especially to view the average-hours effects as potentially realistic.

10. HOW MUCH DOES THE AGE COMPOSITION OF THE LABOUR FORCE MATTER?

We noted earlier that differences in productivity among age groups are not directly observable at the aggregate level. However there is a substantial literature on inferential estimation of age/productivity profiles based on age/wage profiles. An inverse "u-shape" seems well established; Mincer (1974) expressed the natural logarithm of earnings as a linear function of years of education and a quadratic function of potential work experience and, as Murphy and Welch (1990, p 203) observed, "the quadratic in experience ... has been universally accepted". However, whether wages are a good indicator of productivity remains a question. There is a common perception that older workers are overpaid and younger ones underpaid; for example, for the US, Hellerstein and Neumark (2004) estimate that workers over 55 are roughly 20 percent overpaid and younger workers about 10 percent underpaid. Crépon et al. (2003) find similar differences in France. At the same time, many authors find no evidence that the wage profile differs from the productivity profile; among them are Dostie (2011) for Canada, van Ours and Stoeldraijer (2011) for the Netherlands, and Mahlberg et al. (2013) for Austria.

What we do here is to arbitrarily choose a profile roughly consistent with suggestions in the literature, implement it for all countries by resetting the q values (previously set to 1) in equation (3), and then recalculate the $\bar{d}$ values shown previously in Table 2. We can thus get some idea as to how much the projections of population aging on GDP per capita might be affected if we were able to incorporate actual profiles in the calculations. The q values are fixed over time in equation (3); changing them thus amounts only to changing the a_{x0} weights in the equation; the weights are the same in both base and projection years.

The new age/productivity profile reflects the assumption of lower productivity at younger ages and again at older ages. Specifically the q values are as follows: $q = 1.0$ for age groups 30-34 to 55-59; $q = 0.5$ for age group 15-19, with linear interpolation for the groups between 15-19 and 30-34; $q = 0.7$ for age groups 70-74 and older, with linear interpolation between 55-59 and 70-74.

Table 10 compares the $\bar{d}$ indexes calculated using the new age/productivity profile with those from Table 2, which assumed a flat profile. The differences are generally very small. The average

difference to one decimal place is 0.0 in 2025 and -0.4 in each of 2035 and 2045; allowing for lower productivity at younger and older ages changes the impact of population aging on GDP per capita only slightly. Another age/productivity profile would produce different effects but our calculations suggest that whatever (plausible) profile one might choose, the effects would be very small. The biggest effects by far come from the increased proportion of dependents in the population, most particularly older dependents.

11. SUMMING UP

Population aging and a rising dependency ratio are widespread demographic characteristics among industrialized nations, now and prospectively for decades to come. We have used a particular set of population projections provided by the United Nations to document this phenomenon for twenty member countries of the OECD. Population projections for an individual country can differ depending on the assumptions about future fertility, mortality, and immigration rates, and they can be revised as the passage of time provides new information. But collectively the outlook across twenty countries seems well established: population aging will be with us for a long time, and so too its economic implications. Prominent among those implications is continuing downward pressure on the ability of an economy to generate output per capita.

We have provided an index-based framework for calculating the prospective effects of population aging on per capita GDP and used it to show what can happen over three decades, starting from 2015. GDP per capita declines in our calculations in each country, in each decade. The rates of decline vary across countries but there is no exception to the declining trend.

A natural question to ask is whether there could be some other type of change on the supply side of an economy to counter the effects of population aging – most especially, could an increase in productivity do the job? To that end we have calculated the productivity growth rate that would be required for each country in each decade to exactly offset those effects, thus keeping GDP per capita at its 2015 level. We have then done the calculation again but assuming GDP per capita to increase by 1 percent per annum, rather than zero – sufficient growth in productivity, that is, to eliminate the effects of aging plus whatever additional increase would be required to have GDP per capita rising by 1 percent per year. Taking the 20 countries as a whole, the average productivity growth rate (a simple unweighted arithmetic average) required to just offset aging effects over the full 30 years from 2015 to 2045 would be 4.2 percent per decade or approximately 0.4 percent per year; to achieve an overall increase of 1 percent in GDP per capita would require an average rate of 15.1 per decade or 1.4 percent per year. Nothing in the calculations has anything to say about whether such rates would be feasible or infeasible; the rates are simply what would be required. However we have provided some comparisons of the rates required to sustain 1 percent per annum growth of per capita GDP with recent ten-year and thirty-year historical rates. The required rates are generally higher than the recent ten-year rates – higher in most countries, much higher in many. There is considerable heterogeneity among countries when thirty-year historical rates are used in the comparison, rather than ten-year rates, but for many countries the projected rates are then lower or at least close to the historical rates. One's view of the attainability of

the projected rates may thus depend on whether one compares them with more recent or longer-term historical rates.

The next question that we addressed is whether there could be offsets to population aging other than productivity growth. We considered, within our framework, possible increases in labour participation rates (representing deferred retirement), reduced unemployment rates, and increases in average hours worked. An increase of 5 percent in average hours did in fact provide substantial offsets to the aging-induced declines in GDP per capita, actually eliminating the declines in many cases in the first decade of the 30-year projection period; the other changes had only minor effects. As we noted an increase of 5 percent in average hours would increase a 40-hour work week to 42 and add 24 minutes to an 8-hour day. The apparent effects of increasing average hours worked on GDP per capita are certainly substantial, although whether or not they would be societally acceptable is open to question, to say the least; our calculations are just that, calculations, with no implication of feasibility. Also, as we pointed out, the assumption in the calculations is that productivity remains the same when the hours change is introduced – the amount of capital per unit of labour and other determinants of productivity are unaltered, that is – and that is an important assumption in judging the apparent effectiveness of increasing average hours.

The final experimental calculation that we did assumed a change in the age/productivity profile of the employed labour force. In the previous calculations age differences were ignored; the profile was assumed to be flat (in the absence of data based on actual measurement). The modified profile assumed lower productivity per worker at the young end of the working-age spectrum and again at the old end, based on suggestions in the relevant literature. Changing the profile altered only slightly our earlier calculations. The age distribution of employees seems to matter relatively little in the overall framework of population aging and GDP per capita.

APPENDIX: DATA AND ASSOCIATED CALCULATIONS

The United Nations population projections are mid-year projections (interpreted for our purposes as close approximations to annual averages). They are provided at five-year intervals, starting in 2015 and extending to 2100, separately for males and females, for five-year age groups from 0-4 to 95-99, and with an open-ended 100-and-over group at the end. The UN source provided also population numbers for the base year 2015. The base year values for r, e, and h that we require for our calculations were carried out using OECD annual average series for L, E, and H, which in turn were derived from survey data provided by the individual countries (the q values are set by us by assumption). The L and E series were available for all countries for five-year age groups, by sex, from 15-19 to 65-69; they were available for most countries up to 70-74, and for some E (but not L) was available up to 80-84. (Unemployment is assumed by us to be zero for older age groups when only E is available; thus $L = E$ in those cases.) Where the data did not allow the calculation of participation rates beyond 70-74 (or 65-69 in some cases, 80-84 in others) we assumed that the rate declined by half for each subsequent age group. Hours series in the form of *usual hours worked on main job* were available for the same age-sex groups as E from OECD (2017b). Also available for each country from OECD (2017a) was average hours *actually worked*, but that only in the aggregate, not for age-sex groups. What we did was to apply an adjustment factor to the usual hours series by multiplying average usual hours in each age-sex group by the overall ratio of actual to usual hours. (The main-job usual hours series do not allow for absences from work because of illness, holidays, or vacation time, according to the OECD definitions, and thus generally overstate hours actually worked; they also do not allow for hours worked at secondary jobs. We suspect that the interpretation of usual hours may vary from country to country but since the adjustment factors are country-specific that should be caught up in the adjustment process, at least roughly. The adjustment factor ranges from 0.74 for Germany to 0.98 for Ireland.)

Special treatment was required for three countries, Japan, Switzerland, and Canada. For Japan, the usual hours series was available only for specified bands: 1-19 hours, 20-29, 30-34, 35-39, and 40+ (OECD, 2017d). We took the mid-point in each band up to 35-39 hours and assumed 43 hours for the 40+ category. For Switzerland, usual hours of work was not reported for the age group 65 and over; here we assumed that the ratio of usual hours for ages 65 and over to usual hours for ages 60-64 was the same as the average ratio for the other countries for which the ratio could be calculated. For Canada, no usual hours series was available from the OECD source. We therefore made an exception to our use-only-OECD labour data rule and used actual average hours worked from Statistics Canada (2017).

As noted in the main body of the text, survey coverage and definitions can vary to some extent from country to country within the OECD reporting framework. Where there are exclusions from the labour force the armed forces would be the largest group in most if not all countries, one would assume. (Some countries explicitly report only the civilian labour force to the OECD.) To see how much difference this exclusion might make we checked the proportions of armed forces in the total labour force in 2014, as reported by The World Bank (2017). The average proportion over all 20 countries was 0.7 percent; the lowest proportion was 0.3 percent (New Zealand), the highest was 2.4 percent (Korea). All but three countries had proportions below 1.0 percent and ten had proportions of 0.5 percent or less. We judge that the exclusion of armed forces from the labour force in some countries but not others would have had

only small effects on our calculations. Whatever the details of the labour force definition in a particular country, the base period values and the projections for that country are mutually consistent.

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Figure 1. Indexes of GDP per Capita When Only the Population Changes (Lower Half); Corresponding Indexes of Productivity Required to Prevent GDP per Capita from Declining (Upper Half)
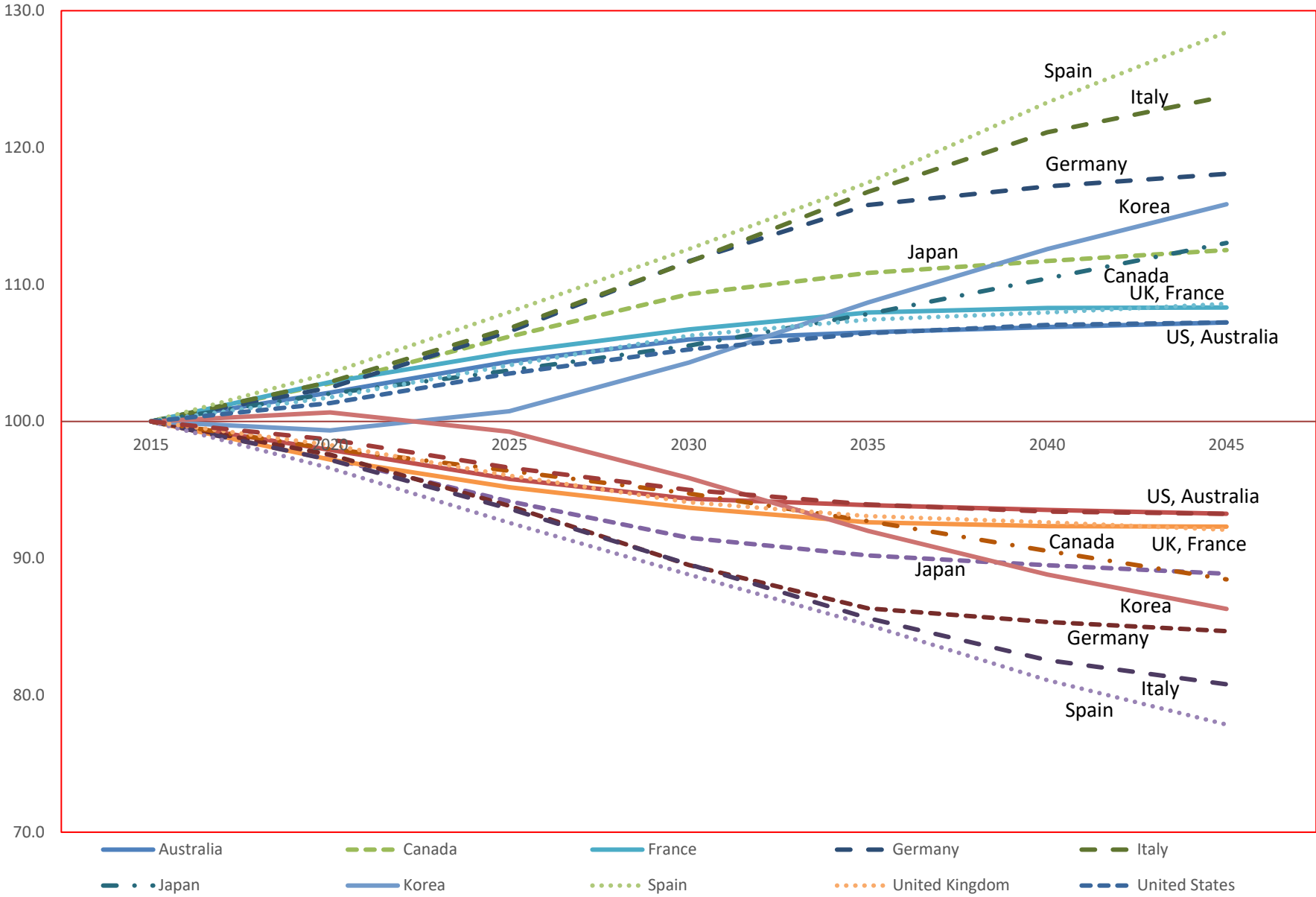
Table 1. Projected Percentages of Population in Dependent Age Groups

	65 and over				Under 20				Under 20 plus 65 and older			
	2015	2025	2035	2045	2015	2025	2035	2045	2015	2025	2035	2045
Australia	15.0	17.8	20.3	21.6	24.9	25.3	24.3	23.1	39.9	43.2	44.6	44.7
Austria	18.8	21.8	27.5	29.7	19.6	19.0	19.0	18.3	38.4	40.8	46.5	48.0
Belgium	18.2	21.0	24.7	26.3	22.4	22.8	21.8	21.3	40.7	43.8	46.5	47.6
Canada	16.1	20.9	24.6	25.7	21.9	21.5	20.7	20.1	38.0	42.5	45.4	45.8
Denmark	19.0	21.3	24.1	24.8	23.2	21.8	22.1	22.1	42.2	43.2	46.2	46.9
Finland	20.5	24.1	26.2	26.1	21.9	21.8	21.1	20.8	42.3	45.9	47.3	46.9
France	19.1	22.4	25.1	26.1	24.4	23.5	22.6	22.5	43.5	45.8	47.7	48.6
Germany	21.2	25.0	30.8	31.6	17.9	17.4	17.5	16.9	39.1	42.4	48.3	48.5
Ireland	13.1	16.6	20.3	24.4	27.5	26.3	22.9	22.8	40.7	42.9	43.1	47.2
Italy	22.4	25.9	31.4	34.9	18.4	17.5	16.9	17.2	40.8	43.4	48.3	52.2
Japan	26.3	29.4	31.9	35.5	17.6	16.8	16.5	16.6	43.9	46.2	48.4	52.1
Korea	13.1	19.7	27.4	33.3	20.5	17.7	17.4	16.4	33.6	37.4	44.9	49.7
Netherlands	18.2	22.5	27.0	27.7	22.4	20.9	20.8	20.6	40.6	43.4	47.8	48.3
New Zealand	14.9	18.8	22.6	23.9	27.0	25.4	23.7	22.8	41.9	44.2	46.3	46.7
Norway	16.3	18.7	21.6	23.2	24.2	23.9	23.4	22.7	40.6	42.7	45.0	45.8
Spain	18.8	22.7	28.8	34.8	19.4	18.3	16.3	16.4	38.2	41.0	45.0	51.2
Sweden	19.9	21.5	23.5	23.7	22.5	24.0	23.4	22.9	42.4	45.4	46.9	46.7
Switzerland	18.0	21.0	25.8	27.6	20.0	20.1	20.1	19.5	38.1	41.1	45.9	47.1
United Kingdom	17.8	19.6	23.1	24.1	23.6	23.9	22.8	22.0	41.4	43.5	45.9	46.1
United States	14.8	18.9	21.4	21.8	25.4	24.6	24.1	23.6	40.2	43.5	45.5	45.4
Average	18.1	21.5	25.4	27.3	22.2	21.6	20.9	20.4	40.3	43.1	46.3	47.8

Table 2. Projected Indexes of GDP per Capita When Only the Population Changes

	Index				Percentage change			
	2015	2025	2035	2045	2015-25	2025-35	2035-45	2015-45
Australia	100.0	95.8	93.9	93.3	-4.2	-2.0	-0.7	-6.7
Austria	100.0	92.7	85.6	82.7	-7.3	-7.7	-3.4	-17.3
Belgium	100.0	93.9	89.2	87.6	-6.1	-5.0	-1.9	-12.4
Canada	100.0	94.2	90.2	88.9	-5.8	-4.2	-1.5	-11.1
Denmark	100.0	98.0	93.7	92.6	-2.0	-4.4	-1.2	-7.4
Finland	100.0	94.9	93.4	93.0	-5.1	-1.6	-0.3	-7.0
France	100.0	95.2	92.6	92.3	-4.8	-2.7	-0.3	-7.7
Germany	100.0	93.8	86.4	84.7	-6.2	-8.0	-1.9	-15.3
Ireland	100.0	95.4	94.5	90.6	-4.6	-1.0	-4.2	-9.4
Italy	100.0	93.6	85.6	80.8	-6.4	-8.5	-5.6	-19.2
Japan	100.0	96.4	92.7	88.5	-3.6	-3.8	-4.6	-11.5
Korea	100.0	99.3	92.0	86.3	-0.7	-7.3	-6.2	-13.7
Netherlands	100.0	94.3	88.9	88.2	-5.7	-5.8	-0.8	-11.8
New Zealand	100.0	97.6	95.2	95.1	-2.4	-2.5	-0.1	-4.9
Norway	100.0	96.5	92.5	90.7	-3.5	-4.1	-2.0	-9.3
Spain	100.0	92.6	85.1	77.9	-7.4	-8.0	-8.6	-22.1
Sweden	100.0	95.9	92.9	92.8	-4.1	-3.1	-0.1	-7.2
Switzerland	100.0	93.6	87.6	85.1	-6.4	-6.4	-2.9	-14.9
United Kingdom	100.0	96.1	93.1	92.1	-3.9	-3.1	-1.1	-7.9
United States	100.0	96.6	93.9	93.3	-3.4	-2.8	-0.7	-6.7
Average	100.0	95.3	91.0	88.8	-4.7	-4.6	-2.4	-11.2

Table 3. Percentage Rates of Growth of Productivity Required in Each Period to Prevent GDP per Capita from Declining

	Growth rate per decade				Growth rate per year			
	2015-25	2025-35	2035-45	2015-45	2015-25	2025-35	2035-45	2015-45
Australia	4.4	2.0	0.7	2.4	0.4	0.2	0.1	0.2
Austria	7.9	8.3	3.5	6.6	0.8	0.8	0.3	0.6
Belgium	6.5	5.2	1.9	4.5	0.6	0.5	0.2	0.4
Canada	6.2	4.4	1.5	4.0	0.6	0.4	0.1	0.4
Denmark	2.0	4.6	1.2	2.6	0.2	0.5	0.1	0.3
Finland	5.4	1.7	0.3	2.4	0.5	0.2	0.0	0.2
France	5.1	2.8	0.3	2.7	0.5	0.3	0.0	0.3
Germany	6.6	8.7	2.0	5.7	0.6	0.8	0.2	0.6
Ireland	4.8	1.0	4.4	3.4	0.5	0.1	0.4	0.3
Italy	6.8	9.3	6.0	7.4	0.7	0.9	0.6	0.7
Japan	3.7	4.0	4.8	4.2	0.4	0.4	0.5	0.4
Korea	0.8	7.9	6.6	5.0	0.1	0.8	0.6	0.5
Netherlands	6.0	6.1	0.8	4.3	0.6	0.6	0.1	0.4
New Zealand	2.5	2.5	0.1	1.7	0.2	0.3	0.0	0.2
Norway	3.6	4.3	2.0	3.3	0.4	0.4	0.2	0.3
Spain	8.0	8.8	9.4	8.7	0.8	0.8	0.9	0.8
Sweden	4.3	3.2	0.1	2.5	0.4	0.3	0.0	0.2
Switzerland	6.8	6.8	3.0	5.5	0.7	0.7	0.3	0.5
United Kingdom	4.1	3.2	1.1	2.8	0.4	0.3	0.1	0.3
United States	3.5	2.8	0.7	2.4	0.3	0.3	0.1	0.2
Average	5.0	5.0	2.6	4.2	0.5	0.5	0.3	0.4

Table 4. Percentage Rates of Growth of Productivity Required in Each Period to Keep GDP per Capita Growing at 1% per Year

	Growth rate per decade				Growth rate per year			
	2015-25	2025-35	2035-45	2015-45	2015-25	2025-35	2035-45	2015-45
Australia	15.3	12.7	11.2	13.1	1.4	1.2	1.1	1.2
Austria	19.2	19.6	14.4	17.7	1.8	1.8	1.4	1.6
Belgium	17.7	16.2	12.6	15.5	1.6	1.5	1.2	1.4
Canada	17.3	15.3	12.1	14.9	1.6	1.4	1.2	1.4
Denmark	12.7	15.6	11.8	13.3	1.2	1.5	1.1	1.3
Finland	16.4	12.3	10.8	13.1	1.5	1.2	1.0	1.2
France	16.0	13.5	10.8	13.4	1.5	1.3	1.0	1.3
Germany	17.7	20.0	12.6	16.8	1.6	1.8	1.2	1.6
Ireland	15.8	11.5	15.3	14.2	1.5	1.1	1.4	1.3
Italy	18.0	20.8	17.1	18.6	1.7	1.9	1.6	1.7
Japan	14.6	14.8	15.8	15.1	1.4	1.4	1.5	1.4
Korea	11.3	19.2	17.8	16.0	1.1	1.8	1.6	1.5
Netherlands	17.1	17.2	11.3	15.2	1.6	1.6	1.1	1.4
New Zealand	13.2	13.3	10.6	12.3	1.2	1.3	1.0	1.2
Norway	14.4	15.2	12.7	14.1	1.4	1.4	1.2	1.3
Spain	19.3	20.1	20.8	20.1	1.8	1.9	1.9	1.8
Sweden	15.2	14.1	10.5	13.2	1.4	1.3	1.0	1.3
Switzerland	18.0	18.0	13.8	16.6	1.7	1.7	1.3	1.5
United Kingdom	15.0	14.0	11.7	13.5	1.4	1.3	1.1	1.3
United States	14.3	13.6	11.3	13.1	1.3	1.3	1.1	1.2
Average	16.0	16.0	13.4	15.1	1.5	1.5	1.3	1.4

Table 5: Comparison of Recent Historical Percentage Rates of Productivity Growth with Projected Rates Required to Keep GDP per Capita Growing at 1% per Year

	Growth rate per decade				Growth rate per year			
	Historical		Projected		Historical		Projected	
	2005 - 2015	1985 - 2015	2015 - 2025	2015 - 2045	2005 - 2015	1985 - 2015	2015 - 2025	2015 - 2045
Australia	13.3	16.1	15.3	13.1	1.3	1.5	1.4	1.2
Austria	11.3	..	19.2	17.7	1.1	..	1.8	1.6
Belgium	5.1	15.7	17.7	15.5	0.5	1.5	1.6	1.4
Canada	8.3	11.3	17.3	14.9	0.8	1.1	1.6	1.4
Denmark	8.2	16.4	12.7	13.3	0.8	1.5	1.2	1.3
Finland	3.9	23.7	16.4	13.1	0.4	2.1	1.5	1.2
France	7.3	17.0	16.0	13.4	0.7	1.6	1.5	1.3
Germany	8.4	17.9	17.7	16.8	0.8	1.7	1.6	1.6
Ireland	49.5	48.3	15.8	14.2	4.1	4.0	1.5	1.3
Italy	0.4	9.5	18.0	18.6	0.0	0.9	1.7	1.7
Japan	7.9	21.8	14.6	15.1	0.8	2.0	1.4	1.4
Korea	38.7	65.3	11.3	16.0	3.3	5.2	1.1	1.5
Netherlands	5.7	11.8	17.1	15.2	0.6	1.1	1.6	1.4
New Zealand	10.6	13.7	13.2	12.3	1.0	1.3	1.2	1.2
Norway	-2.4	16.7	14.4	14.1	-0.2	1.6	1.4	1.3
Spain	13.2	10.4	19.3	20.1	1.2	1.0	1.8	1.8
Sweden	7.9	18.4	15.2	13.2	0.8	1.7	1.4	1.3
Switzerland	6.7	9.2	18.0	16.6	0.7	0.9	1.7	1.5
United Kingdom	4.6	17.1	15.0	13.5	0.5	1.6	1.4	1.3
United States	10.2	16.9	14.3	13.1	1.0	1.6	1.3	1.2
Average	10.9	19.9	16.0	15.1	1.0	1.8	1.5	1.4

Note: The historical series are based on GDP per hour worked (OECD, 2017d); values for Austria for 1985 are not available.

Table 6. Effects on Projected Indexes of GDP per Capita of an Increase in Older-Worker Labour Force Participation Rates (Δr)

	With population change only					With population change plus Δr			
	2015	2025	2035	2045		2015	2025	2035	2045
Australia	100.0	95.8	93.9	93.3		100.0	97.6	95.7	95.1
Austria	100.0	92.7	85.6	82.7		100.0	93.3	86.4	83.4
Belgium	100.0	93.9	89.2	87.6		100.0	94.4	89.8	88.1
Canada	100.0	94.2	90.2	88.9		100.0	96.3	92.4	90.9
Denmark	100.0	98.0	93.7	92.6		100.0	99.2	95.0	93.8
Finland	100.0	94.9	93.4	93.0		100.0	95.9	94.3	94.0
France	100.0	95.2	92.6	92.3		100.0	95.7	93.2	92.8
Germany	100.0	93.8	86.4	84.7		100.0	95.3	88.1	86.1
Ireland	100.0	95.4	94.5	90.6		100.0	97.2	96.6	93.0
Italy	100.0	93.6	85.6	80.8		100.0	94.8	87.0	82.2
Japan	100.0	96.4	92.7	88.5		100.0	100.8	97.3	93.7
Korea	100.0	99.3	92.0	86.3		100.0	103.9	98.1	92.7
Netherlands	100.0	94.3	88.9	88.2		100.0	95.1	89.8	89.0
New Zealand	100.0	97.6	95.2	95.1		100.0	100.4	98.2	97.8
Norway	100.0	96.5	92.5	90.7		100.0	98.2	94.4	92.5
Spain	100.0	92.6	85.1	77.9		100.0	93.1	85.8	78.5
Sweden	100.0	95.9	92.9	92.8		100.0	97.2	94.2	94.1
Switzerland	100.0	93.6	87.6	85.1		100.0	95.0	89.3	86.6
United Kingdom	100.0	96.1	93.1	92.1		100.0	97.4	94.6	93.5
United States	100.0	96.6	93.9	93.3		100.0	99.6	96.9	96.1
Average	100.0	95.3	91.0	88.8		100.0	97.0	92.8	90.7

Note: Δr stands for an increase by half of all labour force participation rates for the population 65 and over between 2015 and 2025; the new rates are held constant thereafter.

Table 7. Effects on Projected Indexes of GDP per Capita of a Decrease in Unemployment Rates (Δu)

	With population change only				With population change plus Δu			
	2015	2025	2035	2045	2015	2025	2035	2045
Australia	100.0	95.8	93.9	93.3	100.0	97.7	95.8	95.1
Austria	100.0	92.7	85.6	82.7	100.0	94.5	87.3	84.3
Belgium	100.0	93.9	89.2	87.6	100.0	96.8	92.0	90.3
Canada	100.0	94.2	90.2	88.9	100.0	96.4	92.4	91.0
Denmark	100.0	98.0	93.7	92.6	100.0	100.0	95.6	94.5
Finland	100.0	94.9	93.4	93.0	100.0	98.0	96.4	96.1
France	100.0	95.2	92.6	92.3	100.0	98.9	96.3	95.9
Germany	100.0	93.8	86.4	84.7	100.0	95.4	87.7	86.1
Ireland	100.0	95.4	94.5	90.6	100.0	98.9	98.0	93.8
Italy	100.0	93.6	85.6	80.8	100.0	97.7	89.5	84.5
Japan	100.0	96.4	92.7	88.5	100.0	97.5	93.8	89.5
Korea	100.0	99.3	92.0	86.3	100.0	100.4	93.0	87.3
Netherlands	100.0	94.3	88.9	88.2	100.0	96.5	90.9	90.2
New Zealand	100.0	97.6	95.2	95.1	100.0	98.4	96.0	95.9
Norway	100.0	96.5	92.5	90.7	100.0	97.1	93.1	91.2
Spain	100.0	92.6	85.1	77.9	100.0	96.5	88.7	81.1
Sweden	100.0	95.9	92.9	92.8	100.0	97.0	93.9	93.9
Switzerland	100.0	93.6	87.6	85.1	100.0	94.3	88.3	85.7
United Kingdom	100.0	96.1	93.1	92.1	100.0	96.8	93.8	92.8
United States	100.0	96.6	93.9	93.3	100.0	97.4	94.7	94.0
Average	100.0	95.3	91.0	88.8	100.0	97.3	92.9	90.7

Note: Δu stands for a reduction of all unemployment rates by one-third between 2015 and 2025; the new rates are held constant thereafter.

Table 8. Effects on Projected Indexes of GDP per Capita of an Increase in Average Hours Worked per Year (Δh)

	With population change only				With population change plus Δh			
	2015	2025	2035	2045	2015	2025	2035	2045
Australia	100.0	95.8	93.9	93.3	100.0	100.6	98.6	97.9
Austria	100.0	92.7	85.6	82.7	100.0	97.3	89.8	86.8
Belgium	100.0	93.9	89.2	87.6	100.0	98.6	93.7	91.9
Canada	100.0	94.2	90.2	88.9	100.0	98.9	94.7	93.3
Denmark	100.0	98.0	93.7	92.6	100.0	102.9	98.4	97.2
Finland	100.0	94.9	93.4	93.0	100.0	99.6	98.0	97.7
France	100.0	95.2	92.6	92.3	100.0	100.0	97.3	96.9
Germany	100.0	93.8	86.4	84.7	100.0	98.5	90.7	88.9
Ireland	100.0	95.4	94.5	90.6	100.0	100.2	99.2	95.1
Italy	100.0	93.6	85.6	80.8	100.0	98.3	89.9	84.8
Japan	100.0	96.4	92.7	88.5	100.0	101.2	97.4	92.9
Korea	100.0	99.3	92.0	86.3	100.0	104.2	96.6	90.6
Netherlands	100.0	94.3	88.9	88.2	100.0	99.1	93.3	92.6
New Zealand	100.0	97.6	95.2	95.1	100.0	102.5	99.9	99.8
Norway	100.0	96.5	92.5	90.7	100.0	101.3	97.2	95.2
Spain	100.0	92.6	85.1	77.9	100.0	97.2	89.4	81.8
Sweden	100.0	95.9	92.9	92.8	100.0	100.7	97.5	97.5
Switzerland	100.0	93.6	87.6	85.1	100.0	98.3	92.0	89.3
United Kingdom	100.0	96.1	93.1	92.1	100.0	100.9	97.7	96.7
United States	100.0	96.6	93.9	93.3	100.0	101.5	98.6	97.9
Average	100.0	95.3	91.0	88.8	100.0	100.1	95.5	93.3

Note: Δh stands for a general increase of 5 percent in average hours worked between 2015 and 2025; the new levels are held constant thereafter.

Table 9. Combined Effects on Projected Indexes of GDP per Capita of Increased Labour Force Participation Rates (Δr), Decreased Unemployment Rates (Δu), and Increased Average Hours Worked per Year (Δh)

	With population change only				With population change plus Δh			
	2015	2025	2035	2045	2015	2025	2035	2045
Australia	100.0	95.8	93.9	93.3	100.0	104.5	102.5	101.8
Austria	100.0	92.7	85.6	82.7	100.0	99.9	92.5	89.3
Belgium	100.0	93.9	89.2	87.6	100.0	102.1	97.2	95.4
Canada	100.0	94.2	90.2	88.9	100.0	103.5	99.3	97.7
Denmark	100.0	98.0	93.7	92.6	100.0	106.3	101.8	100.5
Finland	100.0	94.9	93.4	93.0	100.0	104.0	102.3	101.9
France	100.0	95.2	92.6	92.3	100.0	104.4	101.6	101.2
Germany	100.0	93.8	86.4	84.7	100.0	101.6	93.9	91.8
Ireland	100.0	95.4	94.5	90.6	100.0	105.8	105.1	101.1
Italy	100.0	93.6	85.6	80.8	100.0	103.8	95.4	90.1
Japan	100.0	96.4	92.7	88.5	100.0	107.0	103.4	99.5
Korea	100.0	99.3	92.0	86.3	100.0	110.3	104.1	98.4
Netherlands	100.0	94.3	88.9	88.2	100.0	102.2	96.4	95.6
New Zealand	100.0	97.6	95.2	95.1	100.0	106.3	103.9	103.5
Norway	100.0	96.5	92.5	90.7	100.0	103.7	99.6	97.6
Spain	100.0	92.6	85.1	77.9	100.0	101.8	93.8	85.9
Sweden	100.0	95.9	92.9	92.8	100.0	103.1	100.1	99.9
Switzerland	100.0	93.6	87.6	85.1	100.0	100.4	94.4	91.6
United Kingdom	100.0	96.1	93.1	92.1	100.0	103.0	100.1	98.9
United States	100.0	96.6	93.9	93.3	100.0	105.4	102.6	101.6
Average	100.0	95.3	91.0	88.8	100.0	104.0	99.5	97.2

Note: See Tables 6, 7, 8 for definitions of Δr, Δu, Δh.

Table 10. Effects on Projected Indexes of GDP per Capita of Alternative Assumptions About Age-Related Productivity (Δq)

	Without Δq				With Δq			
	2015	2025	2035	2045	2015	2025	2035	2045
Australia	100.0	95.8	93.9	93.3	100.0	96.1	93.7	93.2
Austria	100.0	92.7	85.6	82.7	100.0	93.2	85.7	82.4
Belgium	100.0	93.9	89.2	87.6	100.0	93.9	88.8	87.2
Canada	100.0	94.2	90.2	88.9	100.0	94.2	90.0	88.7
Denmark	100.0	98.0	93.7	92.6	100.0	98.0	93.9	92.7
Finland	100.0	94.9	93.4	93.0	100.0	95.1	93.4	93.1
France	100.0	95.2	92.6	92.3	100.0	94.8	92.1	92.0
Germany	100.0	93.8	86.4	84.7	100.0	93.8	86.1	84.2
Ireland	100.0	95.4	94.5	90.6	100.0	94.7	93.0	89.5
Italy	100.0	93.6	85.6	80.8	100.0	93.2	84.8	80.1
Japan	100.0	96.4	92.7	88.5	100.0	96.5	92.3	87.6
Korea	100.0	99.3	92.0	86.3	100.0	98.8	90.8	84.5
Netherlands	100.0	94.3	88.9	88.2	100.0	94.0	88.7	88.0
New Zealand	100.0	97.6	95.2	95.1	100.0	97.3	94.9	95.3
Norway	100.0	96.5	92.5	90.7	100.0	96.8	92.4	90.5
Spain	100.0	92.6	85.1	77.9	100.0	92.2	84.1	77.1
Sweden	100.0	95.9	92.9	92.8	100.0	96.5	92.8	92.8
Switzerland	100.0	93.6	87.6	85.1	100.0	93.7	87.2	84.3
United Kingdom	100.0	96.1	93.1	92.1	100.0	96.3	92.8	91.9
United States	100.0	96.6	93.9	93.3	100.0	96.5	93.9	93.2
Average	100.0	95.3	91.0	88.8	100.0	95.3	90.6	88.4

Note: Δq stands for replacement of flat age/productivity profile with profile that has lower productivity at young ages and old ages. See text for details.