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RESEARCH PAPER

Fertility, immigration, and lifetime wages under imperfect labor substitution

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Abstract

This paper provides new insights into the effect of birth cohort size on cohort lifetime wages and its sensitivity to the future trajectories of immigration and fertility. The main innovation is to relax the typical assumption of perfect substitution of labor by age. The effect of imperfect substitution of labor by age is to qualify the standard result that smaller birth cohorts are likely to enjoy relatively high wages since that result depends on the size of co-worker cohorts. The positive small cohort effect on lifetime wages therefore depends on demographic patterns, which are simulated here through low and high fertility and immigration projections. The analysis applies to actual and projected cohorts for Australia and tests the sensitivity to alternative demographic parameters, and the substitution and discount parameters. The effects of imperfect substitution can amount several percentage points of lifetime wages.

Key words: Fertility; immigration; imperfect substitution; intergenerational equity; wages

JEL Classification Numbers: J21; J30; D00

1. Introduction

Easterlin (1978, pp. 401–402) argued that younger and older workers were imperfectly substitutable and therefore the observed relative scarcity of younger male workers in the United States from 1940 to the mid-1970s explained their superior "relative economic position". Easterlin's hypothesis about the effect of relative cohort size on cohort income has received moderate empirical support. A large study of 21 European countries in Moffat and Roth (2013) finds negative effects of cohort size on wages, therefore supporting the Easterlin hypothesis, with the effect being stronger shortly after entering the labor market and stronger for more educated workers. Moffat and Roth note that their findings are consistent with most, but not all, of the prior econometric studies.

This is the first paper that applies an analytical framework in order to show an Easterlin effect of immigration and fertility on the lifetime wages of future cohorts. Under imperfect labor substitution by age, lifetime wages depend on the size of the birth cohorts of co-workers—indeed the wages of birth cohorts are interdependent.

The sizes of co-worker cohorts are in turn affected by trajectories for fertility and immigration which are applied in the simulations here. The idea that workers of different ages are perfectly substitutable is intuitively implausible. Skills and attributes differ with age, including physical capacity, judgment, maturity, ability to assimilate new knowledge, interpersonal skills [Guest and Shacklock (2005)]. The assumption of perfect substitutability by age implies, for example, that the marginal contribution of an additional 25 year old to a workforce is the same regardless of how many 25 year olds are currently employed—in other words, irrespective of how scarce they are. The assumption of perfect substitution of labor among age cohorts, although still common in demographic-macroeconomic models, has been challenged, tested empirically, and relaxed in a variety of modeling approaches [Levine and Mitchell (1988), Lam (1989), Hamermesh (1993), Kremer and Thomson (1998), Card and Lemieux (2001), Blanchet (2002), Rojas (2005), Guest (2007), Prskawetz *et al.* (2008), Roger and Wasmer (2009), Moffat and Roth (2013)].

Fertig and Schmidt (2003) analyze the effect of imperfect labor substitution by age on wages of large cohorts, which is relevant for the present study. They find through econometric estimation that the size of the cohort effect is not as large in the presence of rigidities in the labor market due to, for example, wage bargaining. Our analysis does not allow for wage rigidities, although we leave this question open for future research. The contribution in this paper is to analyze the potential magnitude of the impact of immigration and fertility on the Easterlin small cohort effect.

Several of the above studies estimate specific elasticities of substitution between age groups of labor. While there is considerable variation, the studies generally find significant finite elasticities. Roger and Wasmer (2009) found constant elasticities of substitution by age for different industries to be <1.5, while Card and Lemieux (2001) found higher elasticities, in the range of 4–6. Levine and Mitchell (1988) find a wider range of elasticities for gender and broad age brackets, some being complements and some with substitution elasticities up to 8. Rojas (2005) is perhaps the only study that introduces imperfect labor substitution into a full macroeconomic Computable General Equilibrium model with overlapping generations of households and cost-minimizing firms. That study investigates the effect of demographic change on relative wages due to imperfect labor substitution and is therefore the closest in aims and approach to the present study. In Rojas (2005), cohort size effects have a significant impact on age-wage profiles; this affects lifecycle saving rates and has positive implications for the government's pension obligations, which is the focus of their study.

One point of departure of the model in this study is in the number of age groups and the implications for substitution. In Rojas (2005) there are only two groups of workers: "less experienced" and "more experienced", which they embed in a Constant Elasticity of Substitution (CES) function of labor. This is a potential restriction. The model in this paper has 11 five-year age groups of labor. Also, the focus of this paper is different—it is concerned with the effect of immigration and fertility on the value of aggregate employment rather than the government's pension obligations, and the model here is applied to Australia whereas the model in Rojas (2005) is applied to Spain. The present study implicitly assumes that age-specific education, returns to education, and labor experience do not change over the projection period or differ between the resident population and new immigrant arrivals. There is no attempt control for the education levels of the initial age cohorts.

The analytical method in this study is to apply an economy-wide CES labor index of workers by age, calibrated for alternative values of the substitution parameter which is sufficiently flexible to allow alternative parameterizations of the imperfect substitutability of labor by age. Firms minimize labor costs by equating the relative marginal contribution of workers by age to their relative wages. The empirical simulations here indicate that the relatively small birth cohorts between 1995 and 2005 increase the lifetime wages of those cohorts by several percentage points, but that plausible fluctuations in immigration and fertility can reduce or increase this by around two percentage points. In the absence of imperfect labor substitution, there would be no small cohort effect, and therefore different immigration and fertility projections would also have no effect on cohort lifetime wages.

This paper also contributes to the considerable literature on the economics of immigration. The literature generally finds that immigration increases average living standards in the destination country, albeit modestly, and that the relatively high concentration of the ages of newly-arrived immigrants in the younger working ages is a contributory factor [McDonald and Kippen (2001) , Withers (2002), Productivity Commission (2006), Bijak *et al.* (2007), McDonald and Temple (2010), Parr and Guest (2014)]. Much evidence also exists on the effects on the owners of capital and various sections of the labor force [e.g., Borjas (2014), Card and Peri (2016)]. However, there has been no analysis of the effects of immigration on the lifetime wages of birth cohorts. This paper provides such analysis, connecting the immigration literature with insights from the Easterlin effect of imperfect labor substitution, which adds a new dimension to public policies targeted at immigration. Similarly, while the relationship between fertility and income at the aggregate level has been considered widely [Fox *et al.* (2019)], the link between fertility and cohort lifetime wages via imperfect labor substitution has not been analyzed.

The focus here on the lifetime wages of birth cohorts has implications for intergenerational equity in that the lifetime wages can affect wealth accumulation, consumption, home ownership, retirement incomes, inheritance, health, and life expectancy [Abeysinghe and Gu (2011), Tamborini *et al.* (2015), Attanasio and Pistaferri (2016), Haan *et al.* (2019)]. Intergenerational equity has become an increasingly prominent issue in public discourse in many advanced countries in the context of concerns about public debt levels, population aging, house prices, and climate change—all of which have intergenerational equity implications [McDonald (2000), Thompson (2003), Stern (2007), Garnaut (2008), Parr (2015), Stebbing and Spies-Butcher (2016), Kendig *et al.* (2019)].

Recent demographic trends allow an empirical exploration of the Easterlin effect in the context of migration and fertility. Following a 45-year period of decline, the annual number of births in more developed countries rose by 5.2% between 2000–05 and 2005–10 [UNPD (2017a)]. The country on which this paper focuses, Australia, had one of the larger increases in births: the annual number of births increased by nearly 26% between 2001 and 2012 [ABS (2014); Figure 1]. This substantial change followed a period of relative stability in the numbers of births. Other countries in which similar increases in births were recorded over the same period include England and Wales (22.4% increase over the same period), Ireland (18.5%), New Zealand (18.7% from 2002 to 2008), and Sweden (18.5%) [CSO (2018), ONS (2018), SCB (2018), Statistics NZ (2018)]. The Easterlin hypothesis would imply that the significantly larger initial size of the post-2012 birth cohorts will adversely affect their lifetime incomes.

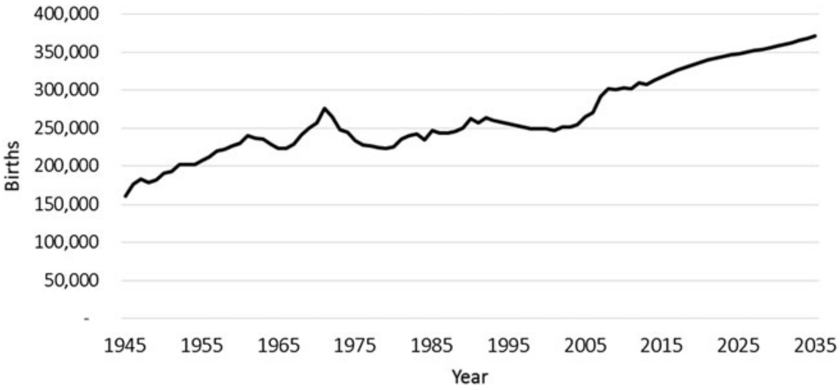

Figure 1. Past and baseline scenario projections of annual births: Australia, 1945–2035.

The percentage of population formed by international immigrants increased considerably in a number of the more developed countries between 2000 and 2017 [UNPD (2017b)]. The ages of international immigrants to such countries (including Australia) are generally concentrated in the younger working ages (i.e., 20–34) at the time of arrival in the destination country [Eurostat (2019)]. Net immigration typically decreases rapidly between the younger and middle working ages, and more gradually between the middle and later working ages. With such an age structure, an increase in immigration to higher than previous levels will increase the sizes of the cohorts in younger working ages relative to the sizes of cohorts in middle and later working ages. Moreover, these differences between cohorts in immigrant population numbers will persist over the remaining lifetime.

Australia is an interesting case both because it has consistently had one of the world's highest rates of net international immigration and because immigration has been a controversial policy issue. Over 2010–15, Australia's rate of net immigration (of 8.6 per 1,000 population) was 3.7 times the average for all more developed countries [UNPD (2017a)]. In 2017, international immigrants formed 29% of Australia's population [ABS (2019a)]. Over the 2009–14 period, the level of net international migration to Australia fluctuated between 178,800 and 229,400 (0.8% and 1.0% of population), with an average of 203,900 [ABS (2015a)]. Similarly, fertility levels have also been an objective of public policy in Australia and other countries. In the mid-2000s, the Australian Government's family policies, including the introduction of "Baby Bonus", appear to have been motivated at least in part by pronatalism [Heard (2006), Parr and Guest (2011)]. In 2005, the Australian Government reported to the United Nations that the national fertility rate was "too low" and its policy was to "raise" it [UNPD (2006)].

2. The model, data, and calibration

2.1 The model

Firms in the economy employ labor inputs, L_i, where $i = 1,\ldots, M$ is the age of the labor inputs (workers). The aggregate quantum of labor, L_t, employed in a firm by the M workers is determined according to the CES labor index:

$$L_t = \left[\sum_{i=1}^{M} \alpha_i L_{i,t}^{\rho} \right]^{1/\rho}, \tag{1}$$

where α_i are the weighting parameters and ρ is the parameter governing the degree of substitution between pairs of $L_{i,t}$. (See section 3 for a comment on the assumption that ρ is age-invariant.) The firm determines the aggregate labor input L_t by minimizing total costs given an aggregate production technology. Our concern here, however, is only with the choice of the labor inputs L_i, having determined the optimal aggregate labor input L_t. The firm chooses L_i by minimizing a cost function: $C = \sum_{i=1}^{M} w_i L_i$. From the standard first-order condition for optimal L_i:

$$\frac{w_{i,t}}{w_{j,t}} = \frac{\partial L_t / \partial L_{i,t}}{\partial L_t / \partial L_{j,t}} = \frac{\alpha_i}{\alpha_j} \left(\frac{L_{i,t}}{L_{j,t}} \right)^{\rho - 1}, \quad i \neq j, \tag{2}$$

where $w_{i,t}$ is the wage of workers of age i in year t. Since L_t is the index value of all workers who are combining with the workers of age i in year t, then $L_{i,t}/L_t$ is a measure of the workforce share of $L_{i,t}$ in year t. For the analysis here, it is important to note that the marginal contribution of $L_{i,t}$ to the aggregate index L_t depends not only on the size of $L_{i,t}$ but also on the size of co-worker cohorts. To see this, note that the marginal contribution $\partial L_t/\partial L_{i,t}$ is given by the differentiation of (1):

$$\frac{\partial L_t}{\partial L_{i,t}} = \alpha_i \left(\frac{L_{i,t}}{L_t} \right)^{\rho - 1}, \quad i = 1, \ldots, M. \tag{3}$$

This helps explain the result in (2) that the relative wage of workers depends on their relative labor size. Further we can show how the relative wage of a worker of age i responds to a change in its own size and the size of workers of another age, all else constant. The elasticity of the wage ratio, w_i/w_j, with respect to the labor input, L_i is given by:

$$E\left[\frac{w_{i,t}}{w_{j,t}}, L_{i,t} \right] = -1 + \rho < 0; \quad E\left[\frac{w_{j,t}}{w_{i,t}}, L_{i,t} \right] = 1 - \rho > 0. \tag{4}$$

By (4) increasing L_i will always decrease the relative wages of L_i. Moreover, a larger L_i will always increase the relative wages of the other labor groups L_j. The latter result implies that the effect of cohort size on the relative wages of that cohort depends on the absolute size of co-worker cohorts.

It is also noted that the relative size of a birth cohort depends not only on the sizes of past birth cohorts but on the sizes of future birth cohorts which cannot be known in advance of their birth. Moreover, immigration may change the future sizes of all birth cohorts as they progress through their working ages. In other words, history is not sufficient to determine the relative wage of a cohort according to its size.

The discussion in relation to (2) and (4) has implications for the size of the Easterlin effect, which is represented here as the effect of the relative size of a labor cohort on the discounted lifetime wages of that cohort. The discounted lifetime wages of a cohort entering the labor force at year t is given by

$$W_n = \sum_i w_{i,t-1+i}(1+r)^{1-i}, \tag{5}$$

where r is a discount rate. As an example, suppose that a worker is aged $i = 1$ in the year $t = 2005$, then the worker's wage at that time will be $w_{1,2005}$. In order to calculate the wage level, $w_{i,t}$, we specify the aggregate wage bill for the economy:

$$W_t L_t = \sum_i w_{i,t} L_{i,t}, \tag{6}$$

where W_t is the wage per unit of the aggregate labor index, L_t, at time t, which is set exogenously at $W_t = 1$ for all t (this normalization is discussed in section 2.3). Dividing (6) by $w_{1,t}$ and using (2) gives:

$$w_{1,t} = \frac{W_t L_t}{\left(L_{1,t} + \sum_i (w_{i,t}/w_{1,t}) L_{i,t}\right)}, \tag{7}$$

which allows all $w_{i,t}$ to be calculated by substituting for w_1 in (2):

$$w_{i,t} = w_{1,t} \frac{\alpha_i}{\alpha_1} \left(\frac{L_i}{L_1}\right)^{\rho-1}, \ i > 1. \tag{8}$$

Using this method, we calculate the discounted lifetime wages, W_n, for a worker entering the labor force for years between 2014 and 2100. The aim is to show the effect on W_n of alternative migration and fertility projections.

2.2 Data, calibration, and demographic projections

The number of age groups is $M = 11$, consisting of 10 five-year age groups, 15–64, and a group aged 65 and over. The values of L_i/L_t for the base year are given in Table 1. The parameters α_i are the labor input weights and are calibrated to the data variables w_i and L_i given the value of ρ which governs the relative degree of substitutability of workers of a given age with other workers. This calibration uses data on relative wages by age, as follows. Re-arranging (2):

$$\frac{\alpha_i}{\alpha_j} = \frac{w_{i,t}(L_{j,t}/L_t)^{\rho-1}}{w_{j,t}(L_{i,t}/L_t)^{\rho-1}}. \tag{9}$$

To determine the values of w_i, we choose the average values of w_i for full-time employees (persons) for the 10-year period 2002–2011 from ABS (2012). For ρ we apply two cases: $\rho = 0.5$, implying a constant elasticity of substitution by the age of 2.0; (ii) $\rho = 0$ implying an elasticity of 1.0. The ratios α_i/α_j are then determined given the scaling restriction $\sum_{i=1}^{M} \alpha_i = 1$ which allows α_1 to be calculated and hence all α_i to be obtained. The choices of ρ and α_i are interdependent in order to ensure that the calibrations are consistent with the known data for $w_{i,t}$ and $L_{i,t}$ [Temple (2012)]; hence, a change in one of these parameters implies a change in the other. Table 1 gives the values of α_i for alternative assumptions about ρ and the values of L_i/L and w_i for the base year. Given the values for L_i, α_i, and ρ, (1) is solved for the value of

Table 1. Productivity weighting parameter values (α_i) by age (i) and rate of labor substitution (ρ) for baseline projection

Age (i)	α_i, $\rho = 0.5$	α_i, $\rho = 0$
15–19	0.0259	0.0152
20–24	0.0672	0.0655
25–29	0.0980	0.1087
30–34	0.1119	0.1214
35–39	0.1192	0.1287
40–44	0.1210	0.1325
45–49	0.1199	0.1316
50–54	0.1150	0.1225
55–59	0.0992	0.0938
60–64	0.0750	0.0554
65+	0.0477	0.0246

the index, L_t. The optimal values of w_i are then determined for years $t = 2,\ldots h$ from (7) and (8). In calculating discounted lifetime wages, we adopt two reference values: 0% and 5%, which represent a typical range of long run real interest rates for developed countries [Yi and Zhang (2016)].

Projections of future values for $L_{i,t}$ and, hence, L_t are generated by applying age-specific hours worked per person to the projections of the future numbers in the corresponding age group I (assumptions for labor force participation are described below):

$$L_{i,t} = H_{i,t}N_{i,t}, \tag{10}$$

where $H_{i,t}$ denotes the hours worked per person in age group i at time t (i.e., the product of the employment to population ratio for age group i at time t and hours worked per employed person for in age group i at time t) and $N_{i,t}$ is the projected population in age at time t. The future population numbers are projected using the standard cohort component method [Siegel and Swanson (2004)]. A baseline population projection was prepared using the following set of assumptions:

- *Fertility.* All age-specific fertility rates remain constant at 2013 levels. The corresponding total fertility rate (TFR) is 1.89 births per woman [ABS (2014)]. Australia's TFR is higher than that for all more developed countries and its mean age at birth is older [UNPD (2017a)].
- *Mortality.* All age–sex specific mortality rates remain constant at 2013 levels. The corresponding life expectancies at birth are 80.3 years for males and for 84.4 years for females [ABS (2015b)]. For both sexes, life expectancy at birth for Australia is among the highest in the world [UNPD (2017a)].
- *Labor force participation.* This is calculated as hours worked per person. For both sexes for each age group, between 15–19 and 65+ hours worked per person

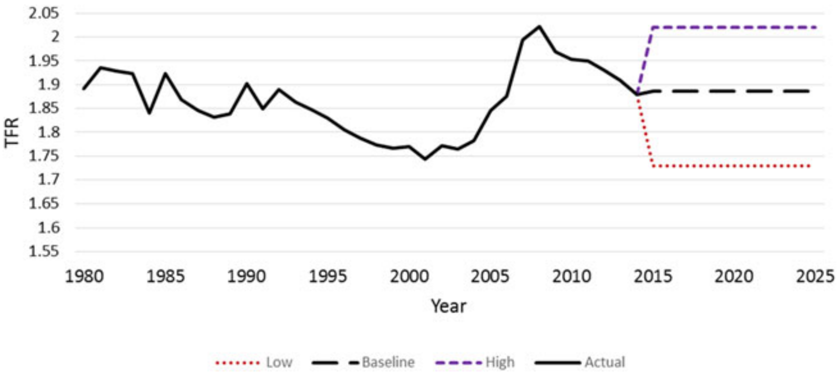

Figure 2. Past and assumed future total fertility rates: Australia 1980–2025.

continues at the average values over the 2010–2014 period [ABS (2015c)]. Average hours worked per person rise steeply between the 15–19 and 25–29 age groups, are broadly similar between the 25–29 and 50–54 age groups, and decrease steeply with increasing age above 55.

- *Net migration.* Annual net migration is 200,000 per annum and the percentage age distributions for net migration are based on the average patterns over the period from 2004 to 2014 [ABS (2016)]. Sixty-two percent of net migration is between the ages of 15 and 34. Australia's rate of net migration is one of the highest in the world, and the mean age of its immigrants is somewhat younger than for other more developed countries for which data are available [United Nations (UNDP) (2017), Eurostat (2019)].

The baseline projection is compared to four variant projections:

(i) Low fertility, which is the lowest TFR over the past 20 years i.e., 2001 (Figure 2).
(ii) High fertility, which is the highest TFR over the past 20 years i.e., 2008 (Figure 2).
(iii) Low immigration, defined as 100,000 per annum net immigration, same percentage age–sex shares as the baseline migration.
(iv) High immigration, defined as 300,000 per annum net immigration, same percentage age–sex shares as the baseline migration.

2.3 Cohort size and lifetime wages

First, we discuss the effects of cohort size on age-specific relative wages (2) for the baseline demographic scenario. We focus on the differences between the birth cohorts "1995–2000" (which spans the youngest working age group i.e., 15–19 in 2015), "2000–05" (which does so in 2020), "2010–15" (in 2025), "2020–25" (2040), and "2030–35" (2050). Figure 1 shows that the initial sizes of the 1995–2000 and 2000–05 birth cohorts are relatively small, and Figure 2 shows the dip in the TFRs over these periods (Figure 2). The TFR recovered after 2000–05 and is assumed to remain at 1.89, which is approximately the average of the past 20 years. The 2010–15

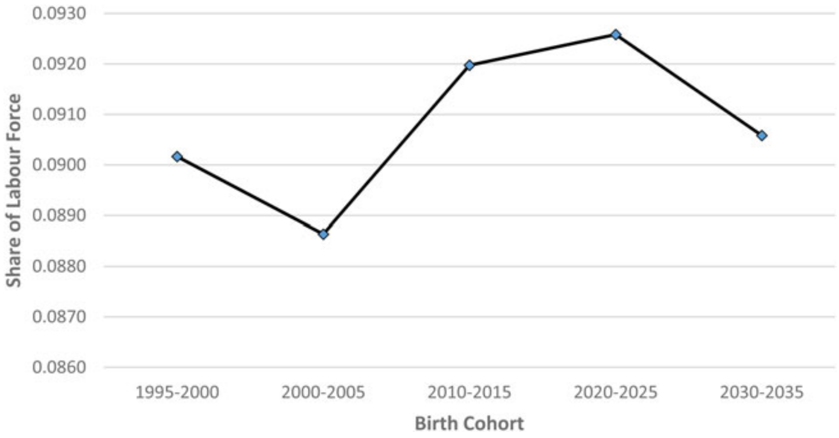

Figure 3. Average lifetime share of labor force by cohort (*n*), baseline demographic scenario.

cohort is projected to be a significantly larger cohort, reflecting the significantly larger numbers of births between 2010 and 2015 (Figure 1). Subsequent cohorts are projected to be larger still in terms of absolute numbers (but not necessarily as a percentage of the working age population). Figure 3 shows the average working lifetime labour force shares $(l_n = \sum_{i=1}^{M} L_{i,n-1+i}/L_t)/M$. The figure shows that $l_{2000-05}$ is slightly lower than $l_{1995-2005}$ and significantly lower than $l_{2010-15}$ which in turn is somewhat higher than $l_{2020-25}$ and $l_{2030-35}$.

Turning to the implications of these relative lifetime labour force shares, l_n, for cohort lifetime wages, W_n, an important qualification is the normalisation $W_t = 1$ in (6). This assumption implies zero productivity-driven aggregate wage growth which would otherwise clearly affect cohort lifetime income and therefore lifetime income inequality. For example, if productivity-driven aggregate wage growth is 1%, cohorts 20 years apart would differ in their lifetime wages by 22% in the absence of any Easterlin effect and all else equal. Given that our focus is on the Easterlin effect and the extent to which it is affected by fertility and migration, aggregate productivity-driven wage growth is assumed to be zero. Given this assumption, the implications of l_n for W_n are shown in Figures 4 and 5 for the baseline demographic projection. More detailed results are discussed in the Appendix which gives tables showing the wages at each age for each cohort under alternative assumptions about the substitution parameter, ρ, and the discount rate, r. Figure 4 shows W_n for a zero discount rate and Figure 5 for a discount rate of 5%. Both figures show W_n for a relatively low ($\rho = 0$) and high ($\rho = 0.5$) substitution elasticity. It is important to note from (3) that under perfect labour substitution, $\rho = 1$, the age-specific wages, w_i, would not change from one cohort to another and nor would the discounted lifetime wage—hence the series in Figures 4 and 5 would be horizontal lines.

For the undiscounted case (Figure 4), W_n for $n = 1995–2000$ is very marginally higher than W_n for $n = 2000–05$ (by 0.1% for $\rho = 0.5$ and 0.3% for $\rho = 0$). The strong similarity of the results for these cohorts reflects the stability in the number of births over the periods when they were (initally) formed (Figure 1). W_n is 1.5% greater for $n = 2000–05$ than for $n = 2010–15$ for the higher substitution case ($\rho = 0.5$) and 3.2%

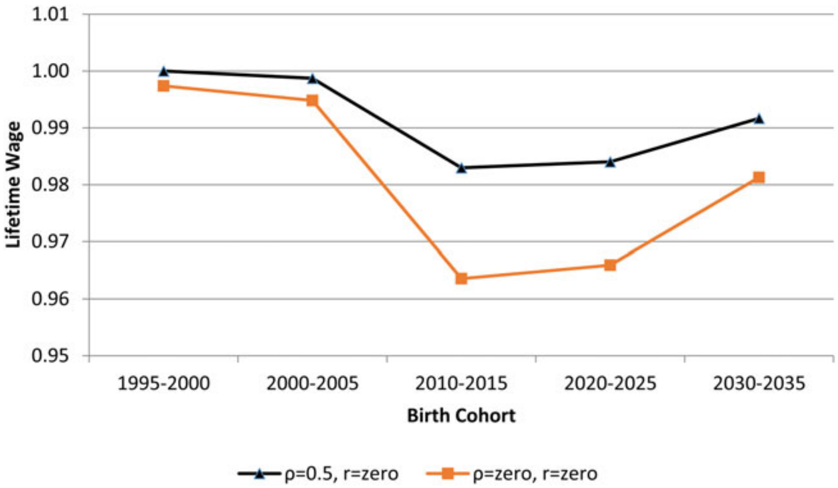

Figure 4. Lifetime wage, $W[n]$. Effect of substitution parameter. Baseline demographic scenario, $r = 0$.

greater for the low substitution case ($\rho = 0$). Hence, the lower substitution case produces a greater effect on cohort lifetime wages. The differences between the results for $n =$ 2000–05 and $n = 2010$–15 illustrate the Easterlin effect of imperfect labour substitution on lifetime wages; and the less the degree of substitution, the greater the effect. For the discounted case where $r = 5\%$ (Figure 5), W_n for $n = 1995$–2000 is virtually identical to $n = 2000$–05 [just 0.02% greater for the higher substitution case ($\rho = 0.5$) and 0.05% greater for the low substitution case ($\rho = 0$)]. In turn, $n = 2000$–05 is 1.6% greater than for $n = 2010$–15 for the higher substitution case ($\rho = 0.5$) and 3.2% greater for the low substitution case ($\rho = 0$). The effect of discounting is therefore small—the effect on W_n on the difference between $n = 2000$–05 and $n =$ 2010–15 is 0.1 percentage points greater under both elasticity parameters. The effects

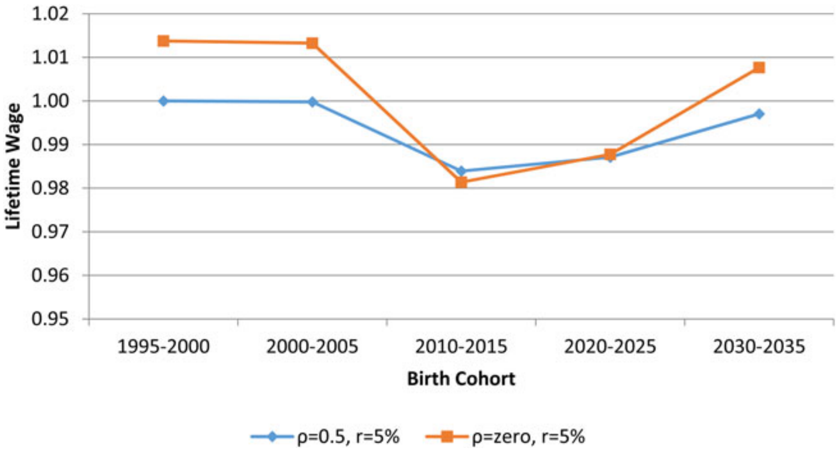

Figure 5. Lifetime wage, $W[n]$. Effect of substitution parameter. Baseline demographic scenario, $r = 5\%$.

of l_n on W_n for the other cohorts in Figures 4 and 5 are entirely consistent with the cases discussed for $n = 2000–05$ and 2010–15. From Figure 3, $l_{2020–25}$ and $l_{2020–25}$ are somewhat higher than $l_{1995–2000}$ and $l_{2000–05}$ and the values of W_n are commensurately lower than $W_{1995–2000}$ and $W_{2000–05}$ (Figures 4 and 5).

In the next section, we discuss the main contribution of this paper, arising from (4), which is to show that the Easterlin effects of l_n on W_n illustrated in Figures 4 and 5 depend on demographic projections for immigration and fertility.

2.4 Migration, fertility, and lifetime wages

2.4.1 Low fertility

Under the low fertility projection, the TFR is constant at 1.73 for all years beyond mid-2015, compared with 1.89 in the baseline projection. The low fertility assumption impacts on the numbers of entrants to the labour force post 2030, and therefore the 1995–2000 and 2000–05 cohorts will be working for most of their working lives with cohorts born during the low fertility period. The effect is that the 1995–2000 and 2000–05 cohorts have smaller successor co-worker cohorts for most of their working lives, and this reduces their marginal contribution to the labour index according to (3) and reduces their wages according to (2), (4) and (5). Hence, the Easterlin small cohort effect is mitigated by the smaller sizes of successor co-worker cohorts. This is illustrated in Figure 6 which shows the average lifetime labour force shares, l_n, for the five demographic projections. In the low fertility projection, the values for l_n for 1995–2000 and 2000–05 are greater than under the baseline projection (by 1.2% and 1.7%, respectively), reflecting the smaller co-worker cohorts under low fertility. The effect is to reduce the lifetime wages, W_n, for the 1995–2000 and 2000–05 cohorts by magnitudes that depend on the degree of labour substitution and the discount rate (Figures 7–10, Table A2). The reductions are smaller for higher labour substitution ($\rho = 0.5$) and higher discount rate ($r = 5\%$) (Figure 8). The lower substitution case ($\rho = 0$) doubles the sizes of the effect on W_n for 1995–2000 and 2000–05, as does eliminating the discount rate. The largest effects are 1.8% for the 1995–2000 cohort and 2.5% for the 2000–05 cohort where $\rho = 0$ and $r = 0$ (Figure 9). Despite the similarity of the sizes of the two cohorts, the effects of the change to fertility on W_n for the 2000–05 cohort are greater than those on 1995–2000, due to the 5-year longer time the latter spends co-working with the cohorts whose size is reduced by the change in fertility (Figures 7–10). That the effects are proportionately greater with a higher discount rate is linked to the 15-year time lag between the change in fertility and its effect on numbers in the labour force.

Whereas under the baseline scenario 2020–25 and 2030–35 are "large cohorts", under the low fertility scenario their initial sizes are reduced to such an extent that their average lifetime labour force shares are similar to those for the 1995–2000 and 2000–05 cohorts (Figure 6). The effects of low fertility on the share labour force ($L_{i,t}/L_t$) are greatest 5–15 years after the entry of these cohorts to the labour force, when their co-worker cohorts are mostly older cohorts whose sizes have not been reduced by low fertility and their labour force participation rate is high. Further in their future, they are working with younger cohorts which, like them, are reduced in size by low fertility, which is why above the age of 45 their $L_{i,t}/L_t$ becomes higher under low fertility than under baseline (Tables A1 and A2). The similarity of their average lifetime share of labour force under the low fertility and baseline scenarios thus is due to a canceling out of trends with different directions at different ages.

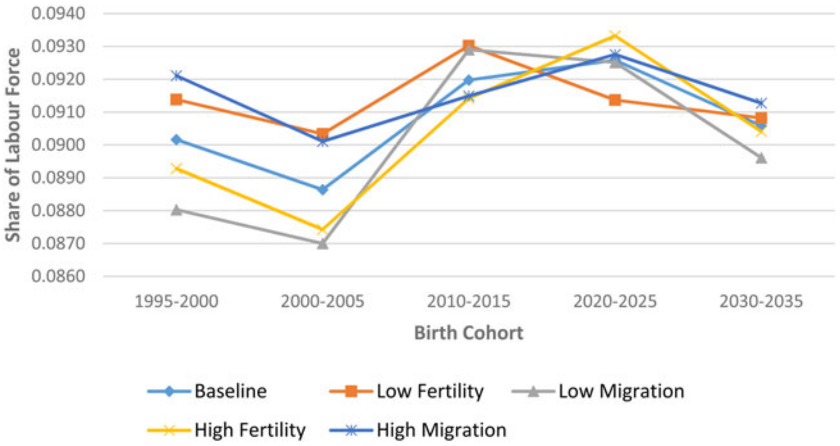

Figure 6. Average lifetime share of labor force by cohort (*n*), various demographic projections.

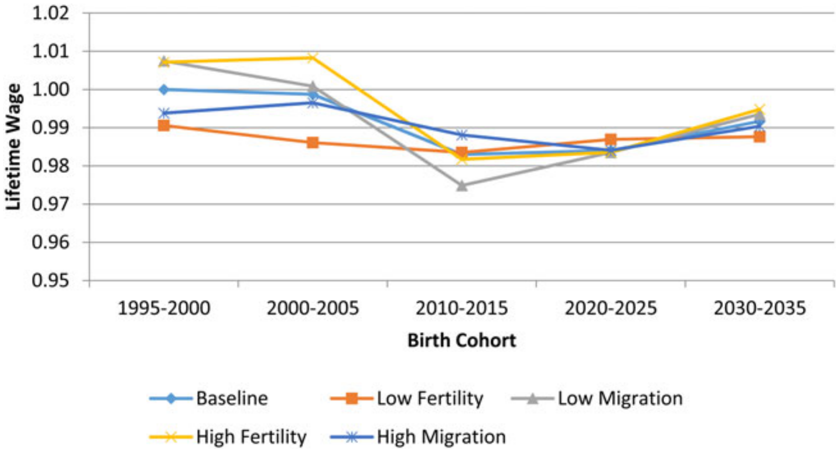

Figure 7. Lifetime wage, $W[n]$. Effect of demographic projection. $\rho = 0.5$, $r = 0$.

The above analysis shows the effect of low fertility on the absolute levels of W_n. We can also compare the 1995–2000 and 2000–05 cohorts and the 2010–15 and subsequent cohorts under low fertility, and compare this with the gap under the baseline projection. This intergenerational comparison is a comparison of the Easterlin effect under baseline and low fertility. The same process that reduces the size of co-worker cohorts and therefore reduces W_n for the 1995–2000 and 2000–05 cohorts, described above, also reduces the intergenerational gap between these and subsequent cohorts in terms of W_n. For baseline demographic scenarios, W_n for the 1995–2000 and 2000–05 cohorts are, respectively, 3.5% and 3.2% above that for the 2010–15 cohort for the low substitution zero discount case (Figure 9). Under low fertility, these differences are reduced to 1.4% and 0.5%, respectively. Hence, in the low fertility case, the small size

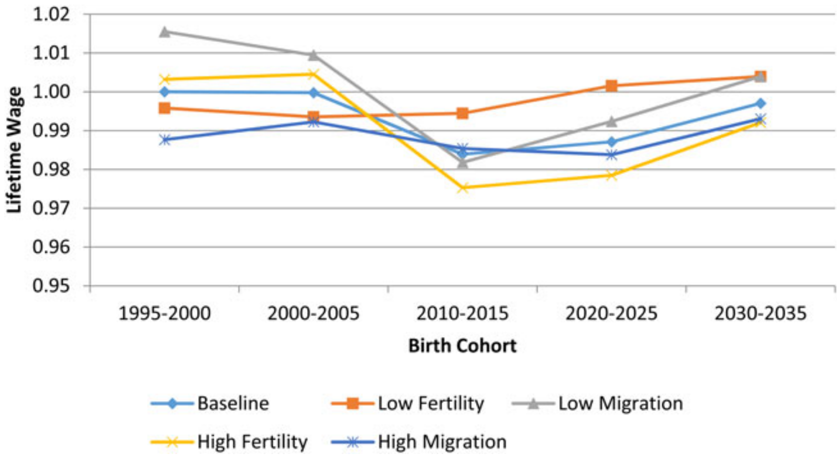

Figure 8. Lifetime wage, $W[n]$. Effect of demographic projection. $\rho = 0.5$, $r = 5\%$.

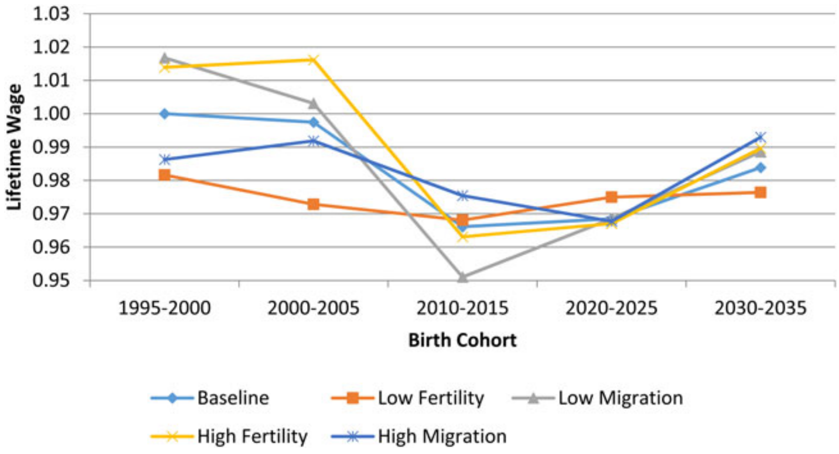

Figure 9. Lifetime wage, $W[n]$. Effect of demographic projection. $\rho = 0$, $r = 0$.

advantages of being in the 1995–2000 and 2000–05 cohorts are reduced considerably relative to 2010–15.

The advantage of the 1995–2000 and 2000–05 cohorts relative to the 2020–25 and 2030–35 cohorts is almost entirely eliminated in the low fertility case. There are slight differences in these magnitudes between substitution and discount assumptions (Figures 7–10). The increases to the value of W_n under the low fertility scenario for the 2020–25 and 2030–35 cohorts are greater under $r = 5\%$ than under $r = 0\%$. This is because for these cohorts, the effect of low fertility on $w_{i,t}$ is positive for the lower values of t (and i) when their co-workers are mostly drawn from older cohorts whose sizes are unchanged by low fertility and negative for the higher values of t when their co-workers are mostly from younger cohorts whose sizes also are reduced by low fertility. Indeed, for the higher values of t (and i), $w_{i,t}$ for the 2020–25 and

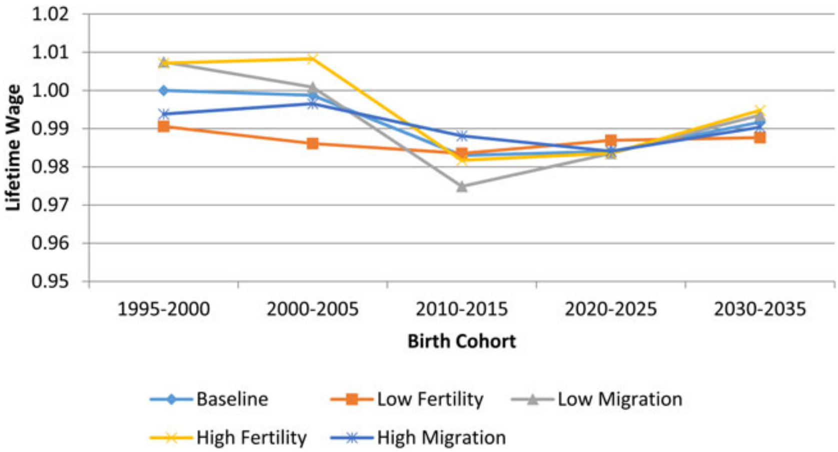

Figure 10. Lifetime wage, $W[n]$. Effect of demographic projection. $\rho = 0$, $r = 5\%$.

2030–35 cohorts are lower under low fertility than under baseline, because of the smaller sizes of their successor cohorts.

2.4.2 High fertility

Under the high fertility projection, the TFR is constant at 2.02 for all years beyond 2015, compared with 1.89 and 1.73 in the baseline and low fertility projections, respectively. The high fertility projection exaggerates the “smallness” of the 1995–2000 and 2000–05 cohorts—l_n is 1.0% less for 1995–2000 and 1.2% less for 2000–05 under high fertility than under the baseline projection. This is because the 1995–2000 and 2000–05 cohorts are working with larger successor co-worker cohorts which raise their marginal contribution to the labour index and hence raise their wages, the opposite to the low fertility outcome. The Easterlin small cohort effect is therefore magnified, reflected in higher lifetime wages, W_n, for the 1995–2000 and 2000–05 cohorts compared with baseline, with the increase being somewhat larger for the latter. The increase in the value of W_n for the 1995–2000 cohort is in the range of 0.3% ($\rho = 0.5$, $r = 5\%$) to 1.4% ($\rho = 0$, $r = 0$), whilst that for 2000–05 is in the range of 0.5% ($\rho = 0.5$, $r = 5\%$) to 2.0% ($\rho = 0$, $r = 0$). Due to the higher fertility, the 2020–2025 and 2030–35 cohorts have larger sizes, as well as having some co-worker cohorts larger sizes. The Easterlin effect, in terms of the gaps in W_n between the 1995–2000 and 2000–05 cohorts and the 2010–15 and subsequent cohorts, is wider under the high fertility scenario than under baseline or low fertility (Figures 7–10, Table A3).

2.4.3 Low immigration

In the low immigration projection, net migration is reduced from 200,000 to 100,000 while maintaining the proportionate age distribution of migrants for each year in the projection period. The results are qualitatively and quantitatively different from those for the low fertility case, in fact the results are closer to those of the high fertility case. The average lifetime labour force shares, l_n, are slightly lower for the 1995–2000 and 2000–05 cohorts under the low migration scenario than under baseline (by 0.2% for both cohorts), whilst the differences for the 2020–25 and 2030–35 cohorts are negligible (Figure 6). The changes in l_n are the net result of increases in labour force shares when the cohorts are in the younger working ages and decrease when they are older. When the "small" 1995–2000 and 2000–05 cohorts first enter the workforce (in 2015 and 2020, respectively), they are working with cohorts whose sizes, in most cases, are less affected by the assumed fall in migration. Consequently, their shares of the labour force are higher than under baseline. Over time, the 1995–2000 and 2000–05 cohorts are joined in the labour force by increasing the numbers of younger cohorts which have been affected by the (assumed) low immigration over a longer time period. As the 1995–2000 and 2000–05 cohorts grow older, the comparison to successor co-worker cohorts, as opposed to predecessor co-worker cohorts, progressively becomes more influential, and the shares of the labour force in the 1995–2000 and 2000–05 cohorts eventually become slightly higher than under baseline.

By the time the 2020–25 and 2030–35 cohorts enter the labour force (in 2040 and 2050, respectively) the assumed low migration has been in effect for longer, and its cumulative effect on the numbers in older co-worker cohorts has been greater. Hence, the reductions to $L_{i,t}/L_t$ for younger age (i) low migration are smaller for the 2020–25 and 2030–35 cohorts than for the 1995–2000 and 2000–05 cohorts, and are balanced by larger increases for older i.

Since the impact on the 2000–05 workforce shares is greater than the impact on the shares for the 2010–15 and 2020–25 cohorts, the average workforce shares of the 1995–2000 and 2000–05 cohorts are even further below those of the 2010–15, 2020–25, and 2030–35 cohorts than in the baseline case (Figure 6). Hence, like the high fertility case, the Easterlin small cohort effect is therefore magnified relative to baseline, reflected in higher lifetime wages, W_n, compared with baseline in the range of 0.8–3.2% for the 1995–2000 cohort and 0.2–2.0% for the 2000–05 cohort, and wider gaps in W_n between these cohorts and the 2010–15 and later cohorts (Figures 7–10, Table A4).

Whilst the overall directions of the effects of low migration on l_n appear broadly similar to those for high fertility (Figure 6), the effects of high fertility and low immigration differ in terms of which cohort sizes are changed and the directions of changes over time (Tables A2–A5). Whereas the effect of high fertility on l_n for the 1995–2000 and 2000–05 cohorts is entirely due to the magnification of the size of co-worker cohorts, the effect of low migration on l_n is the product of shrinkage to differing degrees to these cohorts as well as to their co-worker cohorts. Moreover, there are differences in the timing (and the ages) of the effects of high fertility and low immigration on l_n which also affect the values of W_n. Since the effect of fertility on l_n for the 1995–2000 and 2000–05 cohorts is delayed, whilst the effects of change to immigration are more immediate, the proportionate reduction of W_n by $r = 5\%$ relative to $r = 0\%$ is greater under high fertility (compared to baseline) than under low fertility (as opposed to baseline) migration (Figures 7–10).

2.4.4 High immigration

Under this scenario, net immigrantion is 300,000 per year from 2014 compared with 200,000 in baseline and 100,000 under low net migration with the same proportionate age distribution of migrants as in the other projections for each year. High immigration raises $l_{1995–2000}$ and $l_{2000–05}$ relative to baseline (Figure 6) and reduces $W_{1995–2000}$ and $W_{2000–05}$ commensurately (between 0.6% and 2.5% for $W_{1995–2000}$ and between 0.2% and 1.6% for $W_{2000–05}$). The initially small sizes of the 1995–2000 and 2000–05 cohorts are generally increased by high immigration to a greater extent than their predecessor co-worker cohorts, and therefore the Easterlin small cohort effect is mitigated (Figures 7–10, Table A5).

3. Limitations and sensitivity

The analysis here is partial in that some effects are not modeled. Firstly, the effects of changes in fertility and immigration interact: the effects of changes to immigration depend on fertility levels. Secondly, for simplicity, we ignore the effects of physical and human capital accumulation or education levels. Implicitly, education levels are constant within age groups. We could, for example, have modeled labor of a given age as an index of education levels, as do Roger and Wasmer (2009), but we leave this as a possible future extension. Also, age-specific education levels change over time. In Australia, for example, younger working age cohorts have higher levels of education than older age cohorts. Also, immigrants have higher levels of education than the Australia-born at a given age [Parr (2015)]. However, these effects are further complicated by the observed lower returns to education in terms of occupational status and earnings among the young and among immigrants [Chiswick and Miller (2010), De Alwis and Parr (2018), De Alwis *et al.* (2019), ABS (2019a)]. Moreover, human capital accumulation could be affected as larger cohorts may be more likely to experience larger school class sizes, shortages of resources and of teachers in particular subjects, less choice of schools, higher (private) school fees, greater competition (and hence entry scores) for scarce places at university and in vocational education and training courses. Our modeling also assumes that age-specific labour force participation rates are constant. As in other OECD countries, in Australia, labour force participation rates at ages 55 and above have increased [Parr *et al.* (2016), OECD (2019)]. Our model suggests that the more immediate effect of a continuation of this trend would be to decrease the relative wages of the cohorts which are currently in the older working ages whilst increasing the relative wages of those that are currently in the younger and middle working ages.

Another potential limitation is the assumption that the parameter governing the degree of substitution, ρ, between the pairs of workers of different ages is invariant with respect to age. It is plausible, for example, that middle age workers have a mix of attributes that make them harder to substitute than somewhat younger or older workers, in which case middle-aged workers would have relatively low values for ρ_i, implying a U-shape pattern. Such a U-shape pattern was simulated in Guest and Jensen (2016) . Simulations (not reported) indicate that a U-shape pattern for ρ_i produces quantitative and qualitative effects of fertility and immigration, which are the focus of this paper, that are not materially different to those produced here, where the average value of ρ_i is close to the constant values simulated here, such as $\rho = 0.5$.

Finally, the absence of a government sector in the model does not allow us to determine the cohort effects on taxation revenue and therefore on net wages. The higher wages of the relatively small cohorts may be partly offset by the higher taxes that they must bear, due to their smaller numbers, in order to finance a given level of government spending. Conversely, the lower wages of larger cohorts may be partly boosted by relatively lower taxes due to their greater numbers.

4. Summary and conclusion

The simulations reported here illustrate that the Easterlin small cohort effect on lifetime wages depends on the size of co-worker cohorts. The focus of the simulations is on the

1995–2000 and 2000–05 birth cohorts for Australia, which are relatively small cohorts, and the gap between these cohorts and the 2010–15 cohort and also subsequent cohorts, which are projected to be larger. There are implications for other developed migrant-receiving countries that have experienced similar birth trends to that of Australia, especially England and Wales, Ireland, New Zealand, and Sweden. The four demographic projections simulated here have different implications for the lifetime labour force shares of all the cohorts and for their comparative lifetime wages. The low and high fertility and immigration projections were chosen as a way of illustrating these effects in part because fertility and immigration have been the targets of public policy in Australia and other OECD countries for reasons discussed in the Introducton section. For each demographic projection, two alternative values of the substitution parameter and the discount rate were simulated.

In the baseline projection, lifetime wages for the relatively small 1995–2000 cohort were greater than that for the larger 2010–15 cohort by magnitudes from 1.6% to 3.5% depending mainly on the substitution parameter, ρ. Differences between the (similarly small) 2000–05 and 2010–15 cohorts were only marginally less. The low fertility and high immigration projections reduced the gain in lifetime wages for the 1995–2000 and 2000–05 cohorts compared with subsequent cohorts by up to 2.5%. On the other hand, the high fertility and low immigration projections had the opposite effect: they increased lifetime wages for the 2000–05 cohort and increased the gain in lifetime wages compared with subsequent cohorts by up to 2%. The effects of high fertility and low immigration differ in their effects across time, and therefore the effects are sensitive to the choice of discount rate. Hence, the benefits of being in the relatively small 1995–2000 and 2000–05 cohort are not as great when the low fertility or high immigration assumptions are applied, and are greater for the high fertility or low immigration assumptions. The smaller effect of low fertility on the 1995–2000 cohort is due to the shorter time span it will spend coworking with younger cohorts whose size is diminshed by low fertility. In contrast, the larger effect of high immigration on the 1995–2000 cohort is due to the longer time it spends coworking with older cohorts whose numbers are considerably less affected than it is by the change to high immigration.

Our simulations show that immigration policy, in particular the quantum of immigration, affects intergenerational differences in lifetime wages and the effect depends on the relative sizes of existing generations, the elasticity of labour substitution by age, and the discount rate. Also, a pronatal fertility policy, if successful which is a matter of debate in the literature, could affect the relative prosperity of cohorts [Gauthier (2007), Parr and Guest (2011), Lopoo and Raissian (2018)]. Since 2015, fertility in Australia has fallen and net immigration has generally risen [ABS (2019b)]. Both these changes serve to reduce the small cohort advantage of the millenial cohorts.

Whether the magnitudes found in these simulations are significant is a subjective question that has policy implications. If workers are not indifferent to a 2–3% increase or decrease in their wage on average every year of their working lives, then they may be not indifferent to the immigration or fertility policies that have impacts of that magnitude on lifetime wages. Moreover, the intergenerational analysis here is significant in light of the growing public discourse on intergenerational equity in Australia and other OECD countries, as cited in the Introduction section, where governments face large and growing public debts which some fear impose a burden on future generations. Long run issues that have ignited concern about intergenerational equity include population aging and climate change. The analysis in this paper shows that immigration and fertility can potentially affect intergenerational equity through their impact on cohort size. The analysis therefore connects new insights and evidence on the Easterlin effect with concerns about contemporary impacts on intergenerational equity.

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Appendix

This Appendix presents tables with more detailed simulation results which support the figures in the text. Table A1 provides the results for the baseline projection for cohorts (*n*) born 1995–2000, 2000–05, 2010–15, 2020–25, and 2030–35. The labor force shares, $L_{i,t}/L_t$, and wages, $w_{i,t}$, are given for each age. Underneath each of the columns for $L_{i,t}/L_t$ and $w_{i,t}$ is the average value of these variables over the working lifetime, followed by the discounted lifetime wage, W_n, at each of two discount rates: 5% and 0%. Table A1 is divided into two horizontal blocks, one for each of the two assumptions about labor substitutability.

Table A2 provides the corresponding results for the low fertility projection, Table A3 for the high fertility projection, Table A4 for the low immigration projection, and Table A5 for the high immigration projection.

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Table A1. Projected share of labor force ($L_{i,t}/L_t$), and wage for age group (i) at year (t) and discounted lifetime wages (W_n) for birth cohorts by labor substitutability scenario: baseline projection

Cohort	1995–2000 Cohort			2000–05 Cohort			2010–15 Cohort			2020–25 Cohort			2030–35 Cohort		
Age (i)	t	$L_{i,t}/L_t$	$w_{i,t}$	t	$L_{i,t}/L_t$	$w_{i,t}$	t	$L_{i,t}/L_t$	$w_{i,t}$	t	$L_{i,t}/L_t$	$w_{i,t}$	t	$L_{i,t}/L_t$	$w_{i,t}$
High labor substitutability scenario $\rho_i = 0.5$, all i															
15–19	2015	0.0337	0.449	2020	0.0329	0.454	2030	0.0348	0.4416	2040	0.0348	0.4413	2050	0.0338	0.4482
20–24	2020	0.0884	0.7186	2025	0.0867	0.7255	2035	0.0903	0.7112	2045	0.0901	0.7118	2055	0.0878	0.721
25–29	2025	0.1130	0.9269	2030	0.1106	0.9369	2040	0.1140	0.9228	2050	0.1142	0.9221	2060	0.1111	0.9348
30–34	2030	0.1123	1.0622	2035	0.1096	1.0749	2045	0.1128	1.0596	2055	0.1136	1.0562	2065	0.1102	1.072
35–39	2035	0.1208	1.0907	2040	0.1182	1.1028	2050	0.1223	1.0841	2060	0.1229	1.0813	2070	0.1194	1.0971
40–44	2040	0.1141	1.1388	2045	0.1118	1.1503	2055	0.1164	1.1275	2065	0.1168	1.1257	2075	0.1139	1.1397
45–49	2045	0.1195	1.1026	2050	0.1180	1.1099	2060	0.1228	1.0881	2070	0.1233	1.0859	2080	0.1208	1.0967
50–54	2050	0.1072	1.1169	2055	0.1060	1.1233	2065	0.1102	1.1018	2075	0.1111	1.0971	2085	0.1093	1.106
55–59	2055	0.0880	1.0636	2060	0.0870	1.0698	2070	0.0906	1.0485	2080	0.0919	1.0412	2090	0.0906	1.0486
60–64	2060	0.0571	0.9986	2065	0.0564	1.0044	2075	0.0590	0.9818	2085	0.0601	0.9732	2095	0.0593	0.9797
65+	2065	0.0377	0.782	2070	0.0378	0.7809	2080	0.0385	0.7729	2090	0.0396	0.7621	2100	0.0402	0.7571
Average		0.0902	0.9500		0.0886	0.9575		0.0920	0.9400		0.0926	0.9362		0.0906	0.9455
W_n ($r = 5\%$)			16.5606			16.5572			16.2946			16.3472			16.5117
W_n ($r = 0$)			52.4468			52.3795			51.5537			51.6087			52.0101
Low labor substitutability scenario $\rho_i = 0$, all i															
15–19	2015	0.0337	0.4511	2020	0.0329	0.4608	2030	0.0348	0.4358	2040	0.0349	0.4354	2050	0.0338	0.4489
20–24	2020	0.0885	0.7404	2025	0.0868	0.7547	2035	0.0904	0.7251	2045	0.0902	0.7264	2055	0.0880	0.7450

(*Continued*)

Table A1. (*Continued.*)

Cohort	1995–2000 Cohort			2000–05 Cohort			2010–15 Cohort			2020–25 Cohort			2030–35 Cohort		
Age (i)	t	$L_{i,t}/L_t$	$w_{i,t}$	t	$L_{i,t}/L_t$	$w_{i,t}$	t	$L_{i,t}/L_t$	$w_{i,t}$	t	$L_{i,t}/L_t$	$w_{i,t}$	t	$L_{i,t}/L_t$	$w_{i,t}$
25–29	2025	0.1132	0.9609	2030	0.1108	0.9815	2040	0.1141	0.9527	2050	0.1143	0.9510	2060	0.1113	0.9772
30–34	2030	0.1124	1.0800	2035	0.1098	1.1063	2045	0.1130	1.0751	2055	0.1137	1.0679	2065	0.1104	1.1000
35–39	2035	0.1210	1.0640	2040	0.1183	1.0879	2050	0.1224	1.0511	2060	0.1231	1.0454	2070	0.1196	1.0762
40–44	2040	0.1142	1.1602	2045	0.1120	1.1834	2055	0.1166	1.1365	2065	0.1170	1.1328	2075	0.1141	1.1611
45–49	2045	0.1197	1.1002	2050	0.1181	1.1146	2060	0.1229	1.0709	2070	0.1234	1.0666	2080	0.1210	1.0877
50–54	2050	0.1073	1.1419	2055	0.1061	1.1548	2065	0.1103	1.111	2075	0.1113	1.1013	2085	0.1095	1.1191
55–59	2055	0.0882	1.064	2060	0.0871	1.0765	2070	0.0907	1.0341	2080	0.0920	1.0196	2090	0.0907	1.0339
60–64	2060	0.0571	0.9684	2065	0.0565	0.9795	2075	0.0591	0.9359	2085	0.0602	0.9194	2095	0.0594	0.9316
65+	2065	0.0377	0.6511	2070	0.0378	0.6493	2080	0.0386	0.636	2090	0.0397	0.6183	2100	0.0402	0.6101
Average		0.0903	0.9438		0.0887	0.9590		0.0921	0.9240		0.0927	0.9167		0.0907	0.9355
W_n ($r = 5\%$)			16.7881			16.7801			16.2521			16.3577			16.6873
W_n ($r = 0$)			52.3095			52.1752			50.5365			50.6602			51.4646

Table A2. Projected share of labor force ($L_{i,t}/L_t$) and wage ($w_{i,t}$) of age group (i) in year (t) and discounted lifetime wages (W_n) for birth cohorts, by labor substitutability scenario: low fertility projection

Cohort	1995–2000 Cohort			2000–05 Cohort			2010–15 Cohort			2020–25 Cohort			2030–35 Cohort		
Age	t	$L_{i,t}/L_t$	$w_{i,t}$	t	$L_{i,t}/L_t$	$w_{i,t}$	t	$L_{i,t}/L_t$	$w_{i,t}$	t	$L_{i,t}/L_t$	$w_{i,t}$	t	$L_{i,t}/L_t$	$w_{i,t}$
High labor substitutability scenario, $\rho_i = 0.5$, all i															
15–19	2015	0.0337	0.4490	2020	0.0329	0.4540	2030	0.0338	0.4482	2040	0.0323	0.4584	2050	0.0318	0.4622
20–24	2020	0.0884	0.7186	2025	0.0867	0.7255	2035	0.0881	0.7198	2045	0.0848	0.7339	2055	0.0839	0.7377
25–29	2025	0.1130	0.9269	2030	0.1107	0.9367	2040	0.1122	0.9304	2050	0.1090	0.9441	2060	0.1077	0.9494
30–34	2030	0.1123	1.0620	2035	0.1100	1.0734	2045	0.1120	1.0637	2055	0.1097	1.0746	2065	0.1084	1.0812
35–39	2035	0.1212	1.0891	2040	0.1192	1.0981	2050	0.1225	1.0834	2060	0.1201	1.0938	2070	0.1189	1.0993
40–44	2040	0.1151	1.1341	2045	0.1136	1.1412	2055	0.1177	1.1215	2065	0.1155	1.1321	2075	0.1148	1.1351
45–49	2045	0.1215	1.0939	2050	0.1208	1.0967	2060	0.1252	1.0773	2070	0.1233	1.0857	2080	0.1230	1.0869
50–54	2050	0.1098	1.1035	2055	0.1095	1.1051	2065	0.1135	1.0853	2075	0.1124	1.0909	2085	0.1122	1.0916
55–59	2055	0.0910	1.0463	2060	0.0907	1.0477	2070	0.0944	1.0272	2080	0.0938	1.0306	2090	0.0937	1.0307
60–64	2060	0.0595	0.9780	2065	0.0594	0.9787	2075	0.0622	0.9569	2085	0.0618	0.9595	2095	0.0619	0.9589
65+	2065	0.0397	0.7620	2070	0.0402	0.7569	2080	0.0416	0.7440	2090	0.0423	0.7380	2100	0.0427	0.7343
Average		0.0914	0.9421		0.0903	0.9467		0.0930	0.9325		0.0914	0.9401		0.0908	0.9425
W_n ($r = 5\%$)			16.4909			16.4537			16.4689			16.5862			16.6256
W_n ($r = 0$)			51.9533			51.7176			51.5828			51.7611			51.7975
Low labor substitutability scenario $\rho_i = 0$, all i															
15–19	2015	0.0337	0.4511	2020	0.0329	0.4608	2030	0.0338	0.4488	2040	0.0323	0.4697	2050	0.0318	0.4772
20–24	2020	0.0885	0.7404	2025	0.0868	0.7547	2035	0.0882	0.7429	2045	0.0849	0.7718	2055	0.0841	0.7796

(*Continued*)

Table A2. (*Continued.*)

Cohort	1995–2000 Cohort			2000–05 Cohort			2010–15 Cohort			2020–25 Cohort			2030–35 Cohort		
Age	t	$L_{i,t}/L_t$	$w_{i,t}$	t	$L_{i,t}/L_t$	$w_{i,t}$	t	$L_{i,t}/L_t$	$w_{i,t}$	t	$L_{i,t}/L_t$	$w_{i,t}$	t	$L_{i,t}/L_t$	$w_{i,t}$
25–29	2025	0.1132	0.9609	2030	0.1108	0.9811	2040	0.1123	0.9683	2050	0.1091	0.9962	2060	0.1079	1.0072
30–34	2030	0.1125	1.0795	2035	0.1101	1.1031	2045	0.1122	1.0828	2055	0.1099	1.1048	2065	0.1086	1.1181
35–39	2035	0.1213	1.0608	2040	0.1193	1.0785	2050	0.1227	1.0490	2060	0.1204	1.069	2070	0.1192	1.0794
40–44	2040	0.1152	1.1502	2045	0.1138	1.1642	2055	0.1179	1.1239	2065	0.1157	1.1448	2075	0.1151	1.1506
45–49	2045	0.1216	1.0823	2050	0.1211	1.0875	2060	0.1255	1.0490	2070	0.1236	1.0651	2080	0.1234	1.0672
50–54	2050	0.1100	1.1141	2055	0.1097	1.1171	2065	0.1138	1.0770	2075	0.1127	1.0878	2085	0.1125	1.089
55–59	2055	0.0911	1.0293	2060	0.0909	1.0319	2070	0.0946	0.9915	2080	0.0940	0.9978	2090	0.0940	0.9979
60–64	2060	0.0596	0.9282	2065	0.0595	0.9294	2075	0.0623	0.8881	2085	0.0620	0.8927	2095	0.0621	0.8915
65+	2065	0.0397	0.6178	2070	0.0403	0.6094	2080	0.0417	0.5887	2090	0.0424	0.5792	2100	0.0428	0.5734
Average		0.0915	0.9286		0.0905	0.9380		0.0932	0.9100		0.0915	0.9254		0.0910	0.9301
W_n ($r = 5\%$)			16.6488			16.5739			16.6061			16.8416			16.9188
W_n ($r = 0$)			51.3482			50.8881			50.6404			51.0013			51.0756

Table A3. Projected share of labor force ($L_{i,t}/L_t$) and wage of age group (i) in year (t) and discounted lifetime wages (W_n) for birth cohorts by labor substitutability scenario: high fertility projection

	1995–2000 Cohort			2000–05 Cohort			2010–15 Cohort			2020–25 Cohort			2030–35 Cohort		
Age	t	$L_{i,t}/L_t$	$w_{i,t}$	t	$L_{i,t}/L_t$	$w_{i,t}$	t	$L_{i,t}/L_t$	$w_{i,t}$	t	$L_{i,t}/L_t$	$w_{i,t}$	t	$L_{i,t}/L_t$	$w_{i,t}$
High labor substitutability scenario $\rho_i = 0.5$, all i															
15–19	2015	0.0337	0.4490	2020	0.0329	0.4540	2030	0.0356	0.4363	2040	0.0367	0.4301	2050	0.0353	0.4385
20–24	2020	0.0884	0.7186	2025	0.0867	0.7255	2035	0.0921	0.7041	2045	0.0939	0.6972	2055	0.0908	0.7092
25–29	2025	0.1130	0.9269	2030	0.1106	0.9371	2040	0.1156	0.9164	2050	0.1179	0.9077	2060	0.1136	0.9245
30–34	2030	0.1122	1.0624	2035	0.1094	1.0762	2045	0.1137	1.0556	2055	0.1162	1.0442	2065	0.1116	1.0655
35–39	2035	0.1205	1.0920	2040	0.1174	1.1064	2050	0.1224	1.0837	2060	0.1247	1.0735	2070	0.1197	1.0958
40–44	2040	0.1134	1.1426	2045	0.1105	1.1572	2055	0.1157	1.1365	2065	0.1175	1.1224	2075	0.1132	1.1433
45–49	2045	0.1181	1.1092	2050	0.1159	1.1198	2060	0.1212	1.0802	2070	0.1229	1.0874	2080	0.1192	1.1041
50–54	2050	0.1053	1.1268	2055	0.1035	1.1369	2065	0.1079	1.1183	2075	0.1099	1.1030	2085	0.1072	1.1169
55–59	2055	0.0860	1.0764	2060	0.0844	1.0864	2070	0.0880	1.0475	2080	0.0903	1.0504	2090	0.0882	1.0625
60–64	2060	0.0553	1.0141	2065	0.0543	1.0238	2075	0.0569	1.0049	2085	0.0587	0.9847	2095	0.0574	0.9960
65+	2065	0.0362	0.7971	2070	0.0361	0.7991	2080	0.0365	0.7885	2090	0.0378	0.7805	2100	0.0383	0.7751
Average		0.0893	0.9559		0.0874	0.9657		0.0914	0.9429		0.0933	0.9346		0.0904	0.9483
W_n ($r = 5\%$)			16.6136			16.6355			16.1518			16.2042			16.4295
W_n ($r = 0$)			52.8194			52.8795			51.4876			51.5845			52.1735
Low labor substitutability scenario $\rho_i = 0$, all i															
15–19	2015	0.0337	0.4511	2020	0.0329	0.4608	2030	0.0357	0.4254	2040	0.0367	0.4137	2050	0.0353	0.4297
20–24	2020	0.0885	0.7404	2025	0.0868	0.7547	2035	0.0922	0.7108	2045	0.0940	0.6972	2055	0.0909	0.7210

(*Continued*)

Table A3. (*Continued.*)

	1995–2000 Cohort			2000–05 Cohort			2010–15 Cohort			2020–25 Cohort			2030–35 Cohort		
Age	t	$L_{i,t}/L_t$	$w_{i,t}$	t	$L_{i,t}/L_t$	$w_{i,t}$	t	$L_{i,t}/L_t$	$w_{i,t}$	t	$L_{i,t}/L_t$	$w_{i,t}$	t	$L_{i,t}/L_t$	$w_{i,t}$
25–29	2025	0.1132	0.9609	2030	0.1107	0.9819	2040	0.1157	0.9396	2050	0.1180	0.9217	2060	0.1137	0.956
30–34	2030	0.1124	1.0804	2035	0.1095	1.1089	2045	0.1138	1.0674	2055	0.1163	1.0439	2065	0.1117	1.0871
35–39	2035	0.1207	1.0665	2040	0.1175	1.0951	2050	0.1225	1.0504	2060	0.1249	1.0307	2070	0.1198	1.0740
40–44	2040	0.1134	1.1679	2045	0.1106	1.1978	2055	0.1159	1.1433	2065	0.1176	1.1266	2075	0.1133	1.1690
45–49	2045	0.1182	1.1136	2050	0.1160	1.1347	2060	0.1213	1.0850	2070	0.1230	1.0700	2080	0.1194	1.1030
50–54	2050	0.1054	1.1625	2055	0.1036	1.1829	2065	0.1080	1.1343	2075	0.1100	1.1138	2085	0.1073	1.1419
55–59	2055	0.0861	1.0900	2060	0.0845	1.1103	2070	0.0881	1.0644	2080	0.0904	1.0381	2090	0.0883	1.0619
60–64	2060	0.0554	0.9988	2065	0.0544	1.0180	2075	0.0570	0.9708	2085	0.0588	0.9416	2095	0.0574	0.9633
65+	2065	0.0363	0.6767	2070	0.0361	0.6803	2080	0.0365	0.6727	2090	0.0379	0.6487	2100	0.0384	0.6397
Average		0.0894	0.9553		0.0875	0.9750		0.0915	0.9331		0.0934	0.9133		0.0905	0.9406
W_n ($r = 5\%$)			16.8933			16.9364			15.9670			16.0718			16.5214
W_n ($r = 0$)			53.0364			53.1545			50.3781			50.5871			51.7668

Table A4. Projected share of labor force ($L_{i,t}/L_t$) and wage of age group (i) in year (t) and discounted lifetime wages (W_n) for birth cohorts by labor substitutability scenario: low immigration projection

	1995–2000 Cohort			2000–05 Cohort			2010–15 Cohort			2020–25 Cohort			2030–35 Cohort		
Age	t	$L_{i,t}/L_t$	$w_{i,t}$	t	$L_{i,t}/L_t$	$w_{i,t}$	t	$L_{i,t}/L_t$	$w_{i,t}$	t	$L_{i,t}/L_t$	$w_{i,t}$	t	$L_{i,t}/L_t$	$w_{i,t}$
High labor substitutability scenario $\rho_i = 0.5$, all i															
15–19	2015	0.0333	0.4498	2020	0.0326	0.4551	2030	0.0351	0.4383	2040	0.0346	0.4415	2050	0.0333	0.4500
20–24	2020	0.0849	0.7299	2025	0.0836	0.7356	2035	0.0896	0.7108	2045	0.0885	0.7152	2055	0.0857	0.7266
25–29	2025	0.1066	0.9523	2030	0.1050	0.9593	2040	0.1119	0.9292	2050	0.1114	0.9315	2060	0.1075	0.9481
30–34	2030	0.1056	1.0936	2035	0.1039	1.1025	2045	0.1109	1.0674	2055	0.1109	1.0674	2065	0.1065	1.0890
35–39	2035	0.1145	1.1198	2040	0.1129	1.1277	2050	0.1211	1.0887	2060	0.1206	1.0910	2070	0.1159	1.1129
40–44	2040	0.1095	1.1627	2045	0.1082	1.1698	2055	0.1166	1.1270	2065	0.1155	1.1324	2075	0.1116	1.1520
45–49	2045	0.1167	1.1169	2050	0.1160	1.1203	2060	0.1244	1.0819	2070	0.1232	1.0872	2080	0.1197	1.1031
50–54	2050	0.1067	1.1209	2055	0.1061	1.1244	2065	0.1131	1.0889	2075	0.1126	1.0914	2085	0.1096	1.1061
55–59	2055	0.0893	1.0574	2060	0.0885	1.0624	2070	0.0944	1.0289	2080	0.0944	1.0285	2090	0.0919	1.0428
60–64	2060	0.0589	0.9845	2065	0.0583	0.9899	2075	0.0625	0.9561	2085	0.0626	0.9548	2095	0.0608	0.9689
65+	2065	0.0423	0.7390	2070	0.0419	0.7431	2080	0.0423	0.7392	2090	0.0433	0.7309	2100	0.0432	0.7311
Average		0.0880	0.9570		0.0870	0.9627		0.0929	0.9324		0.0925	0.9338		0.0896	0.9482
W_n ($r = 5\%$)			16.8172			16.7173			16.2598			16.4341			16.6260
W_n ($r = 0$)			52.8380			52.4916			51.1282			51.5826			52.1077
Low labor substitutability scenario $\rho_i = 0$, all i															
15–19	2015	0.0333	0.4528	2020	0.0326	0.4631	2030	0.0352	0.4291	2040	0.0347	0.4356	2050	0.0334	0.4522
20–24	2020	0.0850	0.7642	2025	0.0838	0.7757	2035	0.0897	0.7241	2045	0.0887	0.7327	2055	0.0859	0.7562

(*Continued*)

Table A4. (*Continued.*)

	1995–2000 Cohort			2000–05 Cohort			2010–15 Cohort			2020–25 Cohort			2030–35 Cohort		
Age	t	$L_{i,t}/L_t$	$w_{i,t}$	t	$L_{i,t}/L_t$	$w_{i,t}$	t	$L_{i,t}/L_t$	$w_{i,t}$	t	$L_{i,t}/L_t$	$w_{i,t}$	t	$L_{i,t}/L_t$	$w_{i,t}$
25–29	2025	0.1067	1.0143	2030	0.1052	1.0288	2040	0.1121	0.9653	2050	0.1116	0.9698	2060	0.1078	1.0045
30–34	2030	0.1059	1.1445	2035	0.1042	1.1632	2045	0.1111	1.0902	2055	0.1112	1.0899	2065	0.1068	1.1345
35–39	2035	0.1147	1.1211	2040	0.1131	1.1369	2050	0.1214	1.0591	2060	0.1209	1.0636	2070	0.1162	1.1067
40–44	2040	0.1097	1.2086	2045	0.1085	1.2228	2055	0.1169	1.1349	2065	0.1157	1.1459	2075	0.1118	1.1858
45–49	2045	0.1170	1.1280	2050	0.1163	1.1345	2060	0.1247	1.0582	2070	0.1235	1.0686	2080	0.1200	1.0998
50–54	2050	0.1070	1.1492	2055	0.1063	1.1564	2065	0.1134	1.0846	2075	0.1129	1.0895	2085	0.1099	1.1190
55–59	2055	0.0896	1.0511	2060	0.0887	1.0612	2070	0.0946	0.9953	2080	0.0947	0.9945	2090	0.0921	1.0221
60–64	2060	0.0590	0.9407	2065	0.0584	0.9511	2075	0.0626	0.8872	2085	0.0628	0.8847	2095	0.0610	0.9110
65+	2065	0.0424	0.5813	2070	0.0420	0.5877	2080	0.0424	0.5815	2090	0.0434	0.5685	2100	0.0433	0.5688
Average		0.0882	0.9596		0.0872	0.9710		0.0931	0.9100		0.0927	0.9130		0.0898	0.9419
W_n ($r = 5\%$)			17.3212			17.1115			16.1822			16.5312			16.9192
W_n ($r = 0$)			53.1874			52.4723			49.7478			50.6625			51.7108

Table A5. Projected share of labor force ($L_{i,t}/L_t$) and wage of age group (*i*) in year (*t*) and discounted lifetime wages (W_n) for birth cohorts by labor substitutability scenario: high immigration projection

	1995–2000 Cohort			2000–05 Cohort			2010–15 Cohort			2020–25 Cohort			2030–35 Cohort		
Age	t	$L_{i,t}/L_t$	$w_{i,t}$	t	$L_{i,t}/L_t$	$w_{i,t}$	t	$L_{i,t}/L_t$	$w_{i,t}$	t	$L_{i,t}/L_t$	$w_{i,t}$	t	$L_{i,t}/L_t$	$w_{i,t}$
High labor substitutability scenario $\rho_i = 0.5$, all *i*															
15–19	2015	0.0340	0.4483	2020	0.0332	0.4531	2030	0.0345	0.4445	2040	0.0350	0.4413	2050	0.0341	0.4472
20–24	2020	0.0917	0.7087	2025	0.0895	0.7172	2035	0.0909	0.7117	2045	0.0914	0.7100	2055	0.0893	0.7181
25–29	2025	0.1189	0.9060	2030	0.1155	0.9192	2040	0.1157	0.9182	2050	0.1163	0.9161	2060	0.1135	0.9271
30–34	2030	0.1180	1.0376	2035	0.1143	1.0541	2045	0.1144	1.0540	2055	0.1154	1.0491	2065	0.1127	1.0619
35–39	2035	0.1260	1.0685	2040	0.1224	1.0845	2050	0.1232	1.0810	2060	0.1245	1.0751	2070	0.1216	1.0877
40–44	2040	0.1177	1.1209	2045	0.1146	1.1361	2055	0.1163	1.1283	2065	0.1177	1.1212	2075	0.1154	1.1322
45–49	2045	0.1217	1.0919	2050	0.1194	1.1023	2060	0.1217	1.0868	2070	0.1233	1.0847	2080	0.1215	1.0926
50–54	2050	0.1076	1.1135	2055	0.1059	1.1220	2065	0.1083	1.1107	2075	0.1102	1.1000	2085	0.1092	1.1053
55–59	2055	0.0872	1.0673	2060	0.0860	1.0743	2070	0.0882	1.0540	2080	0.0903	1.0485	2090	0.0898	1.0514
60–64	2060	0.0558	1.0078	2065	0.0552	1.0135	2075	0.0569	0.9994	2085	0.0586	0.9839	2095	0.0584	0.9853
65+	2065	0.0346	0.8138	2070	0.0352	0.8075	2080	0.0363	0.7897	2090	0.0376	0.7815	2100	0.0385	0.7722
Average		0.0921	0.9440		0.0901	0.9531		0.0915	0.9435		0.0928	0.9374		0.0913	0.9437
W_n ($r = 5\%$)			16.3563			16.4320			16.3189			16.2923			16.4460
W_n ($r = 0$)			52.1205			52.2632			51.8228			51.6112			51.9427
Low labor substitutability scenario $\rho_i = 0$, all *i*															
15–19	2015	0.0340	0.4495	2020	0.0333	0.4587	2030	0.0346	0.4413	2040	0.0351	0.4353	2050	0.0341	0.4470
20–24	2020	0.0918	0.7198	2025	0.0896	0.7371	2035	0.0910	0.7260	2045	0.0914	0.7227	2055	0.0894	0.7393

(*Continued*)

Table A5. (*Continued.*)

	1995–2000 Cohort			2000–05 Cohort			2010–15 Cohort			2020–25 Cohort			2030–35 Cohort		
Age	t	$L_{i,t}/L_t$	$w_{i,t}$	t	$L_{i,t}/L_t$	$w_{i,t}$	t	$L_{i,t}/L_t$	$w_{i,t}$	t	$L_{i,t}/L_t$	$w_{i,t}$	t	$L_{i,t}/L_t$	$w_{i,t}$
25–29	2025	0.1190	0.9177	2030	0.1156	0.9444	2040	0.1158	0.9431	2050	0.1163	0.9389	2060	0.1136	0.9611
30–34	2030	0.1182	1.0300	2035	0.1145	1.0635	2045	0.1144	1.0639	2055	0.1155	1.0537	2065	0.1128	1.0794
35–39	2035	0.1262	1.0207	2040	0.1224	1.0519	2050	0.1232	1.0451	2060	0.1246	1.0336	2070	0.1218	1.0578
40–44	2040	0.1178	1.1237	2045	0.1146	1.1545	2055	0.1164	1.1368	2065	0.1178	1.1238	2075	0.1155	1.1458
45–49	2045	0.1217	1.0788	2050	0.1195	1.0995	2060	0.1218	1.0784	2070	0.1234	1.0641	2080	0.1217	1.0794
50–54	2050	0.1076	1.1351	2055	0.1060	1.1522	2065	0.1084	1.1273	2075	0.1103	1.1072	2085	0.1093	1.1176
55–59	2055	0.0872	1.0716	2060	0.0861	1.0855	2070	0.0883	1.0585	2080	0.0904	1.0338	2090	0.0900	1.0393
60–64	2060	0.0559	0.9863	2065	0.0553	0.9974	2075	0.0570	0.9671	2085	0.0587	0.9396	2095	0.0585	0.9422
65+	2065	0.0347	0.7050	2070	0.0352	0.6942	2080	0.0363	0.6727	2090	0.0376	0.6499	2100	0.0385	0.6345
Average		0.0922	0.9307		0.0902	0.9490		0.0916	0.9327		0.0928	0.9184		0.0914	0.9312
W_n ($r = 5\%$)			16.3651			16.5163			16.2937			16.2434			16.5505
W_n ($r = 0$)			51.5912			51.8839			51.0246			50.6230			51.2918