Modelling the Effects of Demographic Changes

We present a theoretical framework to explore the effects of demographic changes on the structure of the economy and the neutral interest rate. The framework captures the key sources of demographic change relevant for the Australian economy, including the rate of population growth, life expectancy and trends in employment arising from later retirement and increased labour force participation of working-age people. In this note, we show that the model produces plausible estimates of the effects of demographic changes on the economy's steady state and describe the mechanisms that lead to these effects.

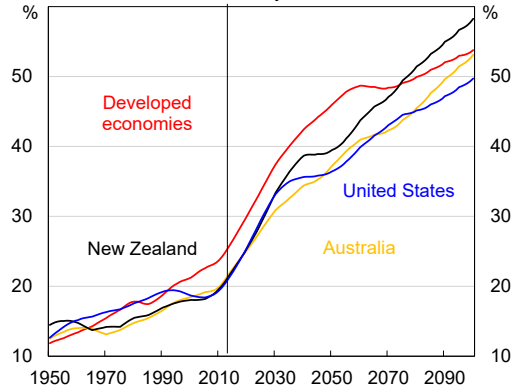
Between 1950 and 2050, the model predicts a substantial accumulation of assets by households in response to demographic changes. This has a modest effect on consumption and investment shares. But it leads to a 300 basis point fall in the neutral interest rate between 1950 and 2000, with a further 100 basis point decline predicted between 2000 and 2050. Later retirement and higher working-age labour force participation offset pressures on publically-provided pension spending. In future work we could model transitional dynamics or add richness to these results by extending the model.

Introduction

Advanced economies are undergoing an unprecedented demographic transition (see Brown & Guttmann (2017) for more details). For Australia, three sources of demographic changes are important for this transition. The first two effects increase the dependency ratio (Graph 1), while the third mitigates some of the economic effects of population ageing.

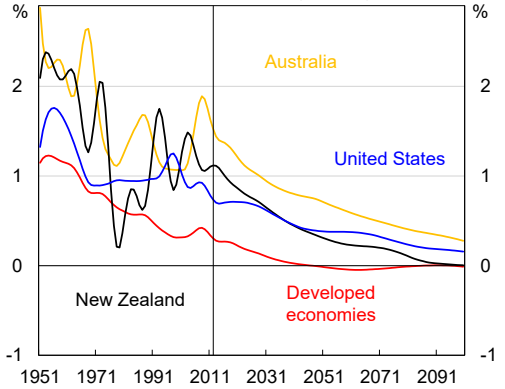
1. Slowing population growth (Graph 2) driven by falling fertility rates.
2. Increased life expectancy (Graph 3).
3. Trends in participation, with more working-age people working (Graph 4) and later retirement.

Graph 1
Dependency ratios
65+ / 15-64 year olds



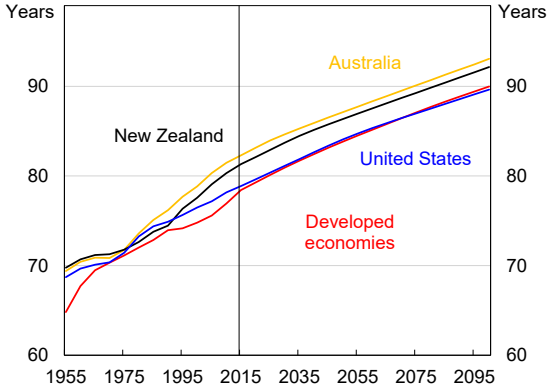
* Developed economies includes North America, Europe, Australia, New Zealand and Japan.
Source: United Nations

Graph 2
Population growth
Year-ended percentage change



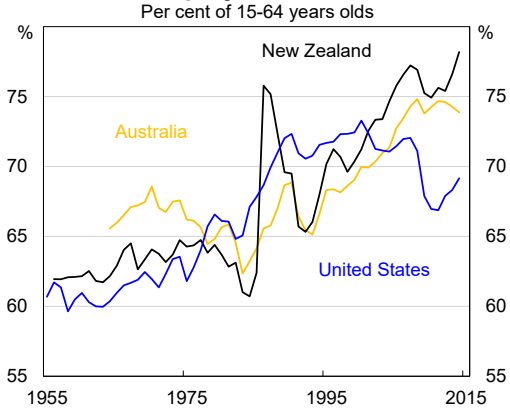
* Developed economies includes North America, Europe, Australia, New Zealand and Japan.
Source: United Nations

Graph 3
Life expectancy
Years at birth, both sexes



* Developed economies includes North America, Europe, Australia, New Zealand and Japan.
Source: United Nations

Graph 4
Employment rates
Per cent of 15-64 years olds



Source: OECD

This note introduces a theoretical framework to explore the effects of demographic changes on the structure of the economy and the neutral interest rate. The framework extends the lifecycle models of Carvalho, Ferrero & Nechio (2016) and Gertler (1999), most notably to account for changes in labour force participation rates. Derivation of the model can be found in the Appendix.

The Framework

A model is useful for exploring the effects of demographic change because it allows us to consider general equilibrium effects, and because the demographic transition is unprecedented (meaning data is limited). We work with a life-cycle model that captures the key sources of Australia's demographic transition – including changes in participation rates, life expectancy, population growth and average retirement age – while being extremely tractable.[1]

The model features two types of agents – workers and retirees. At the start of each year, a new cohort of individuals enters the economy and adds to the existing labour force.[2] At the end of each year, some workers are forced to retire, to be replaced the following year by new workers. While working, individuals receive wage income and returns on their accumulated assets, and use their income to pay taxes, consume and save. After retirement, individuals can no longer work and must consume out of their accumulated wealth and a public pension, which is funded through a lump-sum tax on workers. At the end of each year, retirees face a fixed probability of dying.

Agents are forward-looking and maximise their utility subject to their budget constraints and uncertainty over the length of their working lives and retirement.[3] The need to fund consumption in retirement creates a precautionary saving motive for workers. Uncertainty about the time of death ensures that retirees do not fully draw down on their accumulated assets in retirement.[4] Individuals have two saving vehicles available to them – physical capital and government bonds. Firms use physical capital and labour to produce output, which is allocated for consumption, investment or public demand. The government adjusts taxes to stabilise the government debt-to-GDP ratio, subject to the level of public demand and pension payments to retirees.[5]

The neutral interest rate is determined by the marginal product of capital, which is affected by labour supply and household saving. All else equal, higher household saving boosts the capital-to-labour ratio, reducing the marginal product of capital and the neutral interest rate.

We extend the baseline Gertler (1999) model in two ways:

- As in Carvalho, Ferrero & Nechio (2016), we assume public pensions are 30 per cent of workers' median income (consistent with current benchmarking in Australia), rather than a fixed share of GDP. This means that government pension spending increases as dependency rates increase.
- We allow employment rates of working-age people to vary exogenously over time, reflecting increased participation of women and older people. This is a novel addition.

In our model, population growth, life expectancy, the retirement age, and employment rates of working-age people vary exogenously. Productivity growth is held constant at 1 per cent per year.

There are two caveats to note. We don't think addressing these caveats would change the results qualitatively, although they would provide us with a richer understanding of them.

- The model does not include open economy effects, which can be important for the composition of the economy (e.g. via real exchange rate effects) and the neutral interest rate.
- The treatment of capital markets is simplistic. The capital stock does not include residential housing, government-owned capital or resource investment, which is affected by export prices.

1 Although we work with the non-linear model in this note, it is possible to linearise the model to examine how changes in demographic structure affect the economy's cyclical behaviour, including the transmission of monetary policy. We intend to examine this issue in future work.
2 Workers supply labour inelastically.
3 We abstract from aggregate uncertainty.
4 When people die their assets are redistributed amongst retirees in the next period. Retirement assets can thus be thought of as holdings of in a mutual fund. There are no bequests.
5 Public consumption excluding pensions is assumed to be a constant share of GDP.

Results

To consider how demographic changes affect neutral interest rates and the structure of the economy, we construct three scenarios. We calculate the steady state of the model in each scenario; we do not consider how the economy transitions between steady states, leaving this for further work. Our scenarios approximate Australia's demographic profile in the years 1950, 2000 & 2050. Table 1 summarises the demographic assumptions used for each scenario. The model is calibrated to be consistent with the literature, with a small adjustment to the inter-temporal substitution elasticity to broadly match the Australian data on interest rates and the consumption share of GDP.

Table 1: Demographic scenarios for Australia

	Population	**Life expectancy**	**Employment**	
	Population growth (ye)	Life expectancy at retirement	Employment of working-age people	Average retirement age
1950	2.0%	77	56%	60
2000	1.5%	81	70%	65
2050	1.0%	93*	74%**	70

Note: Employment rate is a share of the population aged 15-64, capturing changes in participation rates in a manner consistent with the model. Life expectancy is for a person entering retirement, based on the associated retirement age – a definition required for the model, which assumes that working-age people ignore the possibility of pre-retirement death in their optimisation.
* Figure is extrapolated forward based on projected trends in life expectancy at birth.
** Figure is extrapolated forward assuming some flattening in the upward trend.
Source: United Nations; OECD; ABS.

Graph 5 shows how changes in population growth, life expectancy and employment rates alter the model's steady state individually, and in combination. The individual effects will not necessarily add to the combined effect. This is a feature of the general equilibrium dynamics in the model; a combination of demographic changes can lead to behavioural responses that reinforce the effects.[6] The effects of each demographic change are considered in turn, before outlining the total effects.

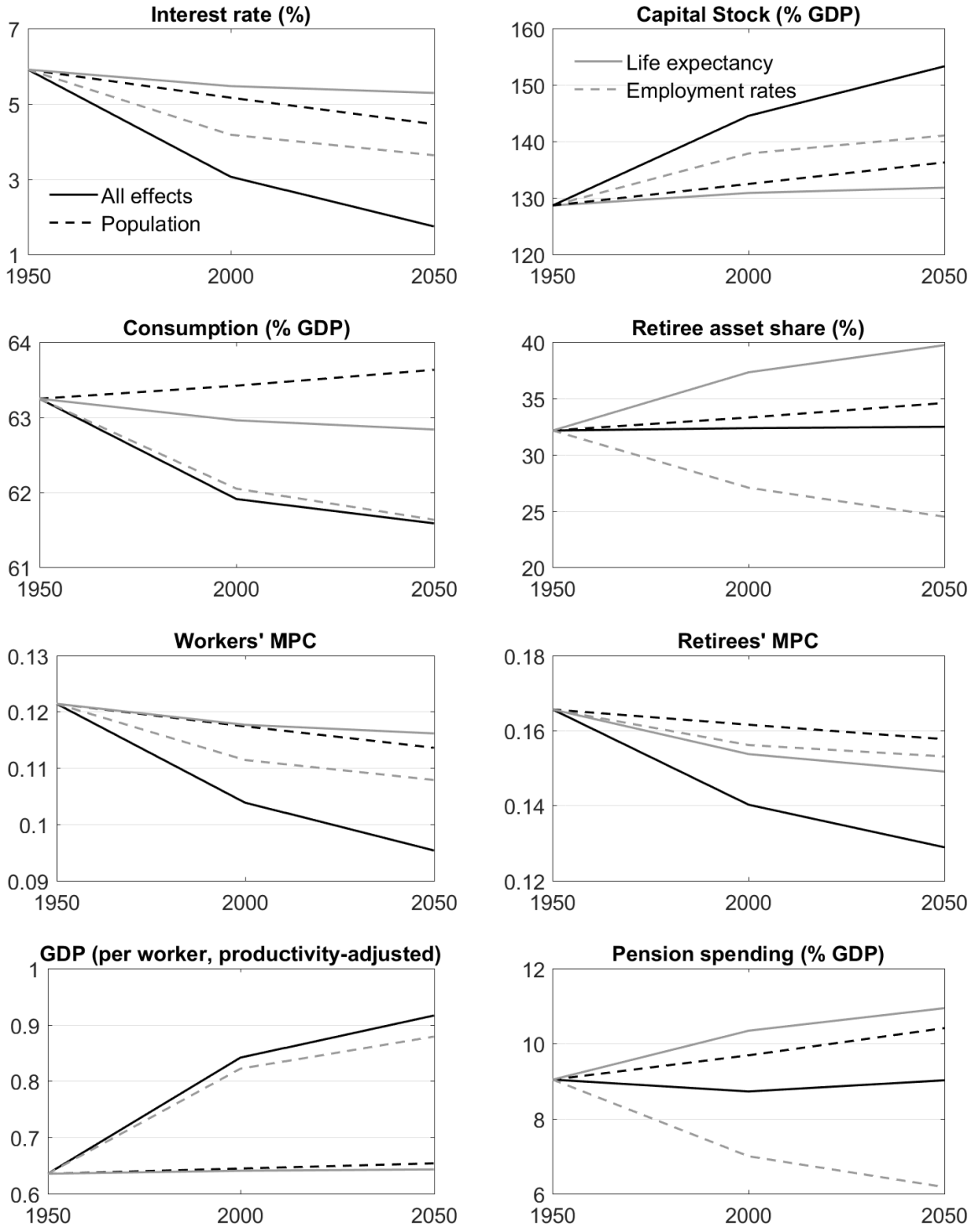
Slower population growth has the following effects:

1. The retiree-to-worker ratio is higher, leading to increased pension spending and taxes.
2. For a fixed saving rate, lower population growth increases the capital-to-labour ratio – assets per person are higher. The marginal product of capital is lower and the neutral interest rate falls.
3. Lower interest rates put downward pressure on consumption by reducing asset incomes – an *income effect*. But they also make consumption more attractive relative to saving – a *substitution effect*. On net, the income effect outweighs the substitution effect, and lower interest rates reduce households' marginal propensity to consume out of lifetime income.[7]
4. Despite households' lower marginal propensity to consume, a larger share of the population is now retirees, who have a higher marginal propensity to consume than workers. Thus, the consumption share of GDP increases slightly. Conversely, the investment share of GDP falls slightly.

Graph 5

6 Put more technically: the steady state is non-linear.

7 Specifically, whether income or substitution effects are dominant depends on households' intertemporal elasticity of substitution. Our parameterisation implies that the income effect outweighs the substitution effect (households have a strong desire to smooth consumption). This seems to be the consensus in the literature (Attanasio and Weber 2010).



Increased life expectancy has the following key effects:

1. The retiree-to-worker ratio is higher, leading to higher pension spending and taxes.
2. Retirees expect to live longer in retirement. To fund their consumption over a longer period, retirees now need to hold more assets. To accumulate these assets and smooth their consumption, households' marginal propensities to consume fall – particularly for retirees.
3. More of the population are retirees, which would tend to increase consumption. However, retirees now consume much less. The lower propensity to consume of retirees dominates (in contrast to the case of increased population). And the consumption share of GDP falls slightly.
4. Higher household saving increases asset holdings, reducing the marginal product of capital and the neutral interest rate.

Increased employment – from higher participation and later retirement – has the following key effects:

1. The retiree-to-worker ratio is much lower, due to older people working longer. This, along with increased participation, reduces pressure on pension spending and taxes.
2. An increase in participation is similar to an exogenous increase in productivity. For a given saving rate, it leads to an exogenous increase in GDP and investment, and thus a larger capital stock. This increase in capital/assets depresses the marginal product of capital and the neutral interest rate.
3. Lower interest rates reduce households' marginal propensity to consume. In addition, higher participation and later retirement imply that a greater proportion of income accrues to workers who have a lower marginal propensity to consume. The consumption share of GDP falls.

Total effects

Slowing population growth, increased life expectancy and trend increases in employment (due to higher participation and later retirement) have the following combined effects:

1. Capital/asset holdings are higher due to three compounding effects:
    a. Slower population growth increases the capital-to-labour ratio.
    b. Increased life expectancy and slower population growth induce workers and retirees to save more to accumulate assets for retirement.
    c. Higher labour force participation and later retirement mean that the capital stock is larger.
2. As a result of these effects, the marginal product of capital is lower, causing a significant downward adjustment of the neutral interest rate. The model predicts a 300 basis points decline in the neutral interest rates between 1950 and 2000 and a 100 basis point decline between 2000 and 2050.
3. Increased life expectancy and lower interest rates reduce households' marginal propensity to consume out of their higher incomes. The consumption share of GDP falls by 1ppt. Conversely, the investment share of GDP increases.
4. The retiree-to-worker ratio is higher, putting upward pressure on pension spending and taxes. Offsetting this, later retirement and increased participation of workers reduce the need for tax-funded pension spending. Overall, pension spending is unchanged as a share of GDP.

Sensitivity of estimates: The adjustment of the neutral interest rate shown here is larger than would be implied by the existing literature due to two key assumptions. First, we adjust the inter-temporal substitution parameter to match the Australian data. If we didn't, the neutral rate would fall by 300 (rather than 400) basis points. Second, we extend the model to include varying participation rates. Without this addition, the neutral interest rate would fall by half as much. We think this is an important effect to include, especially since participation rates have increased so substantially over recent decades.

Conclusion

Using a lifecycle model, we explore the effects of demographic changes, including changes in population growth, life expectancy, and trends in employment (due to higher participation and later retirement). The model predicts substantial accumulation of household savings in response to demographic changes between 1950 and 2050. This has a modest effect on consumption and investment shares. Our results point to a 300 basis point fall in the neutral interest rate between 1950 and 2000, with a further 100 basis point decline predicted between 2000 and 2050. Later retirement and higher labour force participation offset pressures on publically-provided pension spending. This work could be extended to learn more about the transition path between steady states. We could also investigate open economy effects, introduce different types of assets (including housing), or compare scenario results across countries. It is also possible to explore effects of demographic changes on cyclical dynamics and the transmission of monetary policy.

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