ARC Centre of Excellence in Population Ageing Research

Working Paper 2017/03

The Impact of Demographic Change on Labour Supply and Economic Growth: Can APEC Meet the Challenges Ahead?*

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*The paper was commissioned by the Australian Government Department of Employment for the 'Workshop on the Development of an APEC Labour Mobility Framework'.

February 2017

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[1] This paper was commissioned by the Australian Government Department of Employment for the 'Workshop on the Development of an APEC Labour Mobility Framework', taking place in Vietnam in February 2017. The authors are grateful to Andres Villages Ramirez of CEPAR for coding help for the migration flow chart in figure 6 in this paper. They are also grateful to the Australian Government Department of Employment officials, Jabulane Matsebula, Nick Mowbray, and Nick Dowling, for their feedback.
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1. INTRODUCTION

APEC economies encompass a wide range of socio-economic profiles – poor to rich, young to old, regulated to free market. These differences can be instructive for those seeking international policy lessons. They also create new opportunities for cooperation that have the potential to improve wellbeing across member economies. How economies and regions manage demographic change will define their success in what will be an 'ageing century'.[5]

To write an overview paper on the role of demographic change on labour force and economic growth in APEC requires some unifying framework to organise the issues. Here we apply a supply-side, GDP accounting framework to decompose the contribution of population, participation, and productivity to GDP per capita (the 3P's).

We use this modelling to examine historic and projected demographic and macro-economic trends to inform policy discussions and decisions. Section 2 presents this framework and the central projections. Sections 3, 4, and 5 discuss each of the abovementioned three contributors to growth in turn. Section 6 concludes by summarising the findings and policy responses.

2. ECONOMIC GROWTH AND ITS DECOMPOSITION

2.1. Modelling approach: The 3P framework

Monetised economic activity in any given economy can be decomposed into the population available for work, the proportion in employment, and the average level of productivity of workers. This Population-Participation-Productivity (3Ps) framework lends itself to long-term modelling of the aggregate supply-side of GDP, which abstracts from short term cyclical variations.[6] While the results are sensitive to assumptions, particularly relating to productivity, this type of projection is good at capturing the effect of demographic ageing on the labour force and economic activity.

Here we track composition of GDP and GDP per capita outcomes across 21 APEC economies in each year between 1990 and 2050. Methodology and assumptions are further described in Appendix B. But broadly, the calculations are based on the product of historic and projected data relating to (1) population by 5-year-age-group and sex from UN (2015); (2) labour force participation by 5-year-age-group and sex from ILO (2015a); (3) unemployment by age (ages 15-24, 25+) and sex; and (4) productivity (GDP per worker, calculated as a residual based on historic GDP estimates from IMF, 2016, and assumed to converge for the projection).[7]

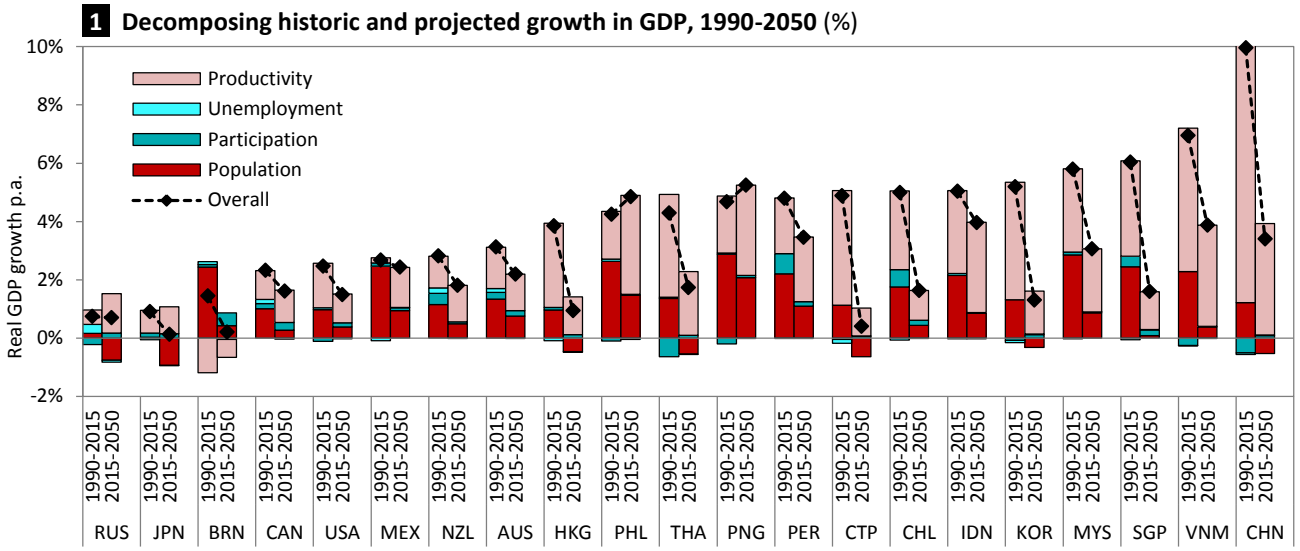
[5] See, for example, Chomik and Piggott (2013) or World Bank (2016) for summary of population trends and necessary policy in the Asia Pacific region.
[6] In many advanced economies (including Australia, Canada, Japan, Korea, New Zealand, and the US) such modelling has become a common part of the long term budgeting and policy development processes (e.g., see OECD 2014a for a summary). Such reports primarily make use of GDP estimates as the denominator for spending projections, thereby evaluating the long term sustainability of government policies.
[7] The method is summarised in the following simplified GDP per capita formula for a given year.
GDP per capita = (Population by age × Participation rate by age × (1-Unemployment rate by age) × GDP per worker)/Total population

2.2. Main results: GDP growth is expected to slow

Figure 1 presents the main results, showing the contribution of each factor to average annual changes in real GDP.[8] Between 1990 and 2015, the Chinese, Vietnamese, and Singaporean economies grew fastest, at between 6% and 10% per annum; those of Russia, Japan, and Brunei grew slowest, at below 1.5%.

In future, economic growth across APEC is projected to slow, from an (unweighted) average of 4.1% per annum between 1990 and 2015, to an average of 2.2% between 2015 and 2050. Those projected to grow fastest, with rates of 4% or above, include Indonesia, Philippines, and Papua New Guinea. China is expected to grow at a modest 3.4% per annum.

In absolute terms, this translates to a Chinese economy in 2050 that is three times larger in real terms than it is today and a Philippine economy that is five times larger. At the other end of the scale, Japan, Brunei, and Chinese Taipei are projected to grow slowly at below 0.5% per annum. Japan's economy is projected to expand negligibly in real terms.



Source: Authors' analysis. Note: Based on (1) medium population variant, (2) trend increase in participation based on ILO projection, (3) unemployment at long term level based on ILO; and (4) convergence of productivity growth. See Appendix B for more details.

2.3. Historic determinants of growth: Youthful populations played an important part

The methodology allows us to look at the components of economic growth. Productivity was the main driver of GDP growth in most economies, and nowhere was this more so than in China, where productivity improvements between 1990 and 2015 were responsible for over 90% of growth. In 1990, the average Chinese worker produced $3,000 of goods and services (at 2015 Purchasing Power Parity – PPP). By 2015, as employment moved from farm to factory, the average worker generated over $25,000, an average annual increase of about 9.3%. By contrast, productivity in the US grew at 1.5% per annum on average over the same period.

But changes in the size and age structure of the population have also played an important role over the last 25 years. Over this period, population changes were responsible for about a quarter of GDP growth

[8] We isolate changes in numbers of people, rates of participation or rates of unemployment *at a given age* as effects of population, participation or unemployment. The effect of productivity is any change in GDP not accounted for by other factors. How do population and participation effects differ? If, for example, numbers of people aged 25-29 increases but the participation of this age group is constant, the increase in production will be entirely due to population changes and none will be ascribed to participation – even though more people are participating in the labour force. Participation effect is counted only when rate by age changes. This is in contrast to some approaches that conflate the two (e.g., Commonwealth of Australia 2015a).

in Korea and Hong Kong, a third in Vietnam and Thailand, a half in Malaysia, and most of the economic growth in Mexico and Brunei.[9]

Historic changes to age-specific labour force participation rates had a smaller effect on GDP; changes to unemployment rates had negligible impact. In Russia, China, and Thailand, declines in participation rates, particularly by university-age and pension-eligible populations dragged on growth. Peru, Chile and New Zealand saw a significant boost to growth due to increases in participation, particularly among the elderly.

Participation rate effects conceal changes by sex. In Thailand, China, and Vietnam, women's participation rates declined alongside those of men and had a strong negative effect; in Korea, Philippines, and Chinese Taipei the rate increased and mostly offset economic effects of drops in participation among men. In places like New Zealand and Peru, both men and women saw increasing, reinforcing rates of participation, which boosted growth.

2.4. Future determinants of growth: Demography as a headwind

In future, the 'demographic dividend' is expected to reverse to become a 'demographic deficit'. It will mean that the working age populations will grow more slowly or decline. This relates not only to the total size of the potential workforce but also its composition: greater proportions of older people, who are less likely to work. Indeed, by 2050 declines in the total labour force are expected in seven economies: China, Hong Kong, Japan, Korea, Russia, Thailand, and Chinese Taipei. As shown in Figure 1, such demographic trends become a headwind to overall economic growth for all seven of these APEC economies. For others, demography is expected to contribute less in future than it has in the past.

Some economies are projected to see increases in participation rates that contribute to growth. These are modelled based on recent and expected trend growth (from the ILO, 2015b) and are not guaranteed. Productivity growth will remain the largest source of growth in future. But since technological transfers from advanced economies are expected to slow, we can assume that upper-middle-income economies such as China, Malaysia, and Mexico will by 2050 converge to a level of productivity growth seen in high income economies. By contrast, lower-middle-income economies such as Indonesia, Philippines, Papua New Guinea, and Vietnam have more catching up to do and are therefore projected to benefit from higher productivity growth for longer (see Appendix B for details about assumptions).

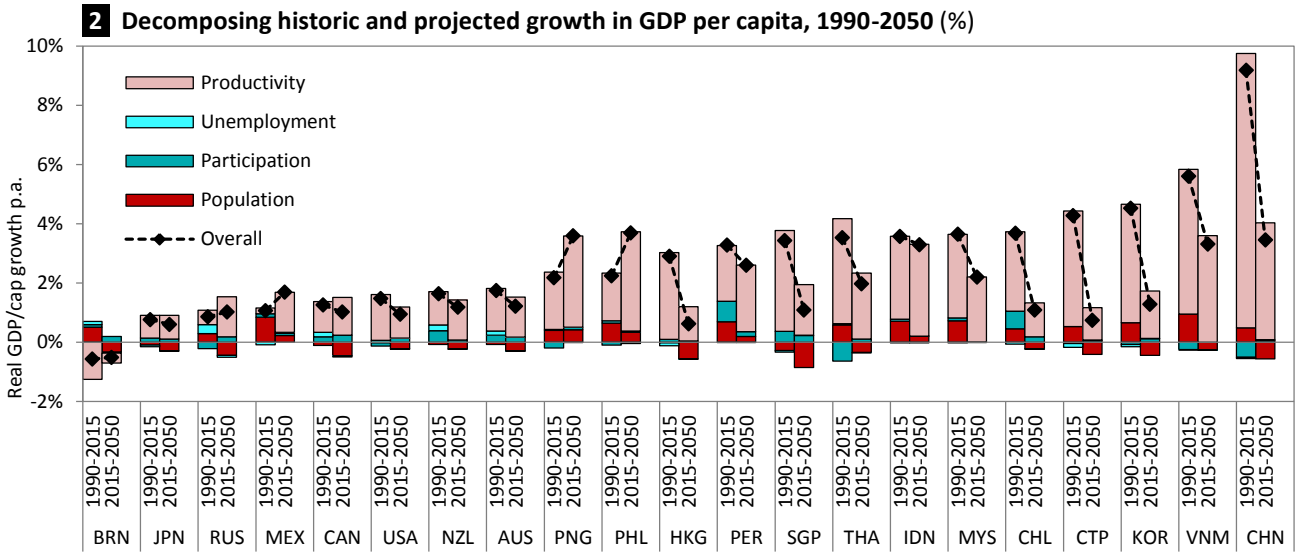
2.5. GDP per capita results: Standards of living to grow more slowly

Results in Figure 2, for GDP per capita, are similar. The measure is important since it acts as a proxy for standards of living.[10] Historic increases in GDP per capita are expected to slow down, with the exceptions of Philippines and Papua New Guinea, which can expect especially high demographic and productivity driven growth, and Mexico and Russia, which had low historic growth.

The effect of population on this measure is more subtle since it contributes to both the numerator and denominator. Still, large shares of younger workers increased average levels of production per person across APEC. In future, this will give way to older populations and lower income growth. The demographic deficit is most apparent for Singapore, Hong Kong, and China. Only PNG, Philippines,

[9] Some of these results are consistent with the scale of the demographic dividend described in the literature. See, for example, Lee et al. (2011), and Golley and Tyers, 2012.
[10] The distribution of such gains is another matter, beyond the scope of this paper.

Mexico, Indonesia, and Peru can expect a positive contribution of population to GDP per capita. Overall, APEC's unweighted average growth of GDP per capita is expected to slow from 2.9% to 1.7% p.a.



Source: Authors' analysis. Note: Based on (1) medium population variant, (2) trend increase in participation based on ILO projection, (3) unemployment at long term level based on ILO; and (4) convergence of productivity growth. See Appendix B for more details.

While demographic projections are relatively reliable, they are subject to assumptions about fertility, mortality and migration. Assumptions about participation, unemployment and productivity are also not set in stone. The future of economic growth will depend on how economies combine the 3P's, probably via a combination of boosting working populations by way of migration, increasing participation rates of existing workers, and making them more productive. In the following sections we discuss each component of growth in more detail, including the related policy levers.

3. POPULATION

3.1. Older populations: Different levels and rates of ageing

Population ageing is taking place APEC-wide. In 1990, about 7% of the region's population was aged 65 or over. The proportion is now 10%, and by 2050, about a quarter of APEC's residents will be 65+.

Population ageing is a relatively predictable process over the medium-term driven mainly by declines in fertility, to a lesser extent by declines in mortality, and moderated by migration. But fertility, mortality and migration vary widely by location and over time, so APEC economies are at different stages of demographic transition.

The level and rate of change in population shares of different age-groups is one set of measures of these shifts. Other measures include dependency and support ratios, ageing pyramids, median population age, etc. Figure 3 presents the 2015 population share of older people (aged 65+) and the expected rate of change of this share between 2015 and 2050 for each APEC economy. Figure 4 does the same for the prime-working-age population (aged 15-64).

Figure 3 shows APEC economies in four quadrants based on where they are relative to the region's unweighted average. The characterisation is helpful in thinking about the broad form, scale and urgency of policy responses. A number of economies are already older and ageing slowly. These include Australia,

Canada, Japan, Russia, New Zealand, and the United States. They are already dealing with the fiscal and economic challenges of ageing, and some are now seeking to rectify past inaction. By contrast, Malaysia, Mexico, Indonesia, Papua New Guinea, Peru, and Philippines are relatively young and ageing more slowly. They are in a position to develop sound policy frameworks in preparation for population ageing.

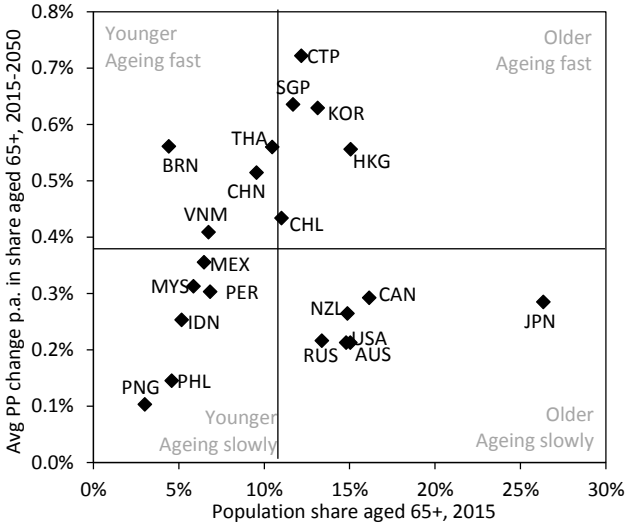
The remaining economies are ageing fast, not only relative to APEC – they are among the fastest ageing societies in the world, with commensurate levels of policy urgency. Some are seeing rapid ageing from a more youthful base, including Brunei, China, Thailand and Vietnam. Others are already old but can expect to still see considerable ageing over the next 35 years. These consist of Chile, Hong Kong, Korea, Singapore, and by this measure, the fasted ageing economy in APEC and the world, Chinese Taipei.

3.2. Working age populations: In decline, but not everywhere

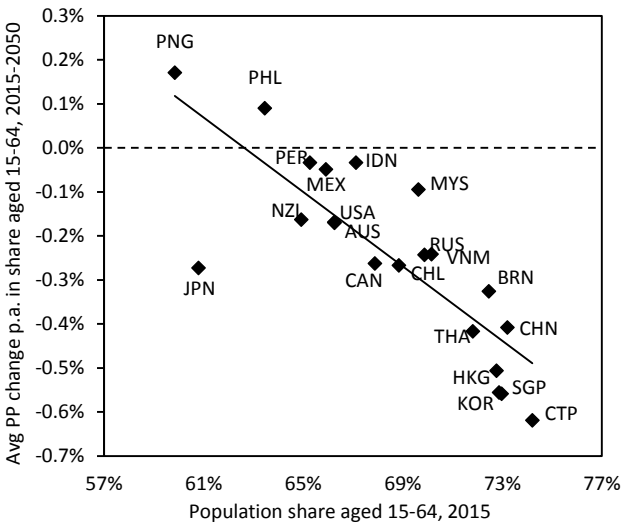
Rapid declines in fertility are related to initial increases in the size of the working-age population relative to the overall population. This is then followed by a rapid relative decline in that age-group. As was shown in section 2 historic increases in potential workers are associated with a temporary increase in the relative size of the workforce and economic activity – the demographic dividend.

This demographic process is seen in Figure 4. For example, Chinese Taipei, Singapore, Hong Kong, and China, have among the largest proportions of working-age people, but they can expect the fastest drop in that population share. By contrast, Philippines and Papua New Guinea are yet to see increases to their working age populations, and Indonesia, Peru and Mexico can expect only small declines by 2050.

3 Share of older people and rate of change



4 Share of working-age and rate of change



Source: Authors' analysis of UN (2015). Note: Figure 3 thresholds are based on APEC unweighted average.

3.3. Permanent migration: Some economies attract more migrants than others

Demographic differences can offer synergies within the block: youthful populations in places with few jobs and low productivity can move to places with high labour demand and productivity, much as has been the case with internal migration to cities. So, to what extent do APEC economies rely on migrants and where are these migrants from?

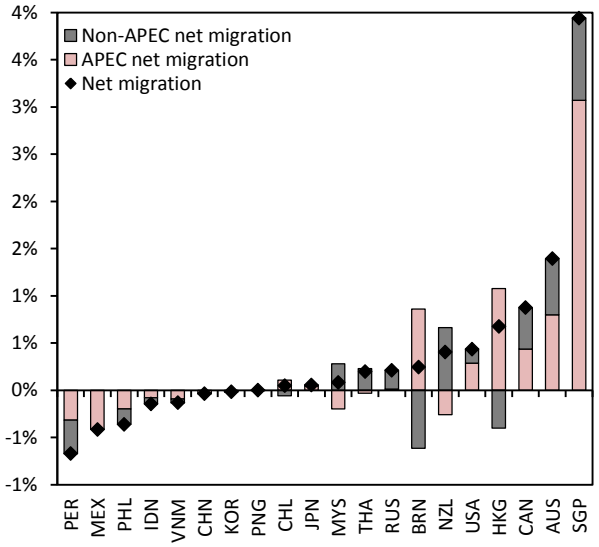
Figure 5 presents net permanent annual migration flows (inflow minus outflow) as a proportion of the total population across APEC between 2005 and 2010. For example, it shows that Singapore is especially

reliant on net inflow of migrants, which accounted for about 4% of its total population. Inward migration was also important for Australia, Canada, and Hong Kong. In absolute terms, Singapore's net inflow represents about 140,000 per annum, which is dwarfed by the net flow into the US of over 900,000, or by the net flows into Russia, Australia or Canada of over 200,000. Peru, by contrast, sees a net outflow of 0.7% of its population. Other sources of migrants, with net outflows, include Mexico and the Philippines.

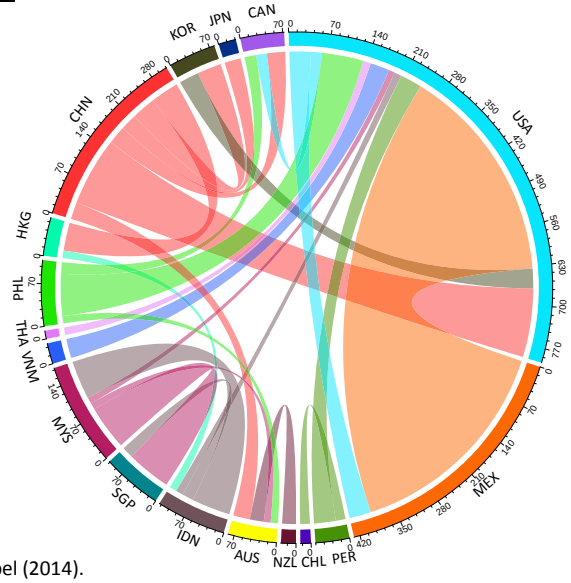
The migration movements in Figure 5 are also split by net flows with APEC and rest of the world. Singapore, Australia, Canada, and the US enjoy net inflows from both APEC and elsewhere. Hong Kong and Brunei see net outflows with the rest of the world but attract a positive flow from APEC economies. Malaysia has a negative net flow with APEC but a larger positive net flow from the rest of the world.

The patterns are further depicted in Figure 6, with respect to intra-APEC migration. It reveals key migrant source and destination relationships, including the flows: from Mexico to the US; Indonesia to Malaysia; Malaysia to Singapore; New Zealand to Australia; and from China to economies across APEC. Russia and Papua New Guinea are missing from this chart, since they have few migrants moving from or to APEC.

5 Annual net migration, 2005-2010 (% of population)



6 Annual intra-APEC migration flows, 2005-2010 (000s)



Source: Authors' analysis of Abel and Sander (2014), and based on code from Abel (2014).
Note: Figure 5: migration denotes permanent migration; net amount denotes inbound minus outbound. Figure 6: migration denotes permanent migration; only flows of above 10k people are shown; the outer arc for each economy represents the sum of inflows and outflows for that economy; the outflows are distinguished from the inflows by the colour of that economy as visible in the outer arc (e.g., the orange flow is from Mexico to the US, while the blue flow is from the US to Mexico; since Australia has no outflows to APEC of above 10k, no yellow coloured flows are visible).

While there are considerable flows in both directions between Mexico and the United States, the data suggests that few pairs of APEC economies have significant two way migration. Quite aside from demographic impacts, a lack of return flows is a concern since return migrants bring home new skills and ideas (see Section 5). However, data in Figures 5 and 6 exclude temporary movements, by definition. [11]

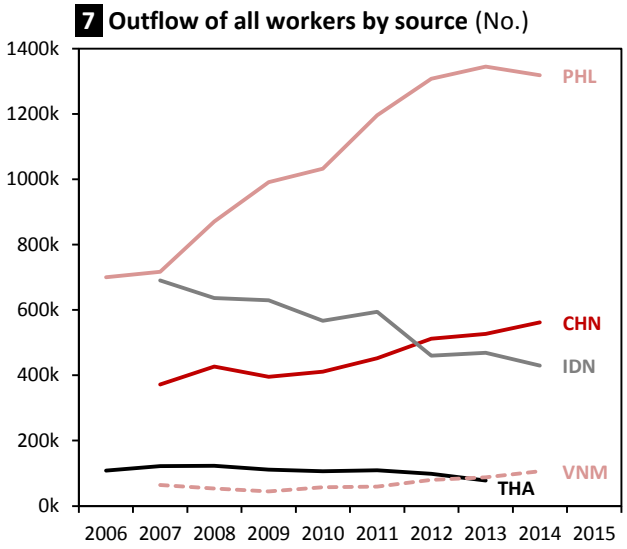
3.4. Temporary migration: Short term labour migration can be significant

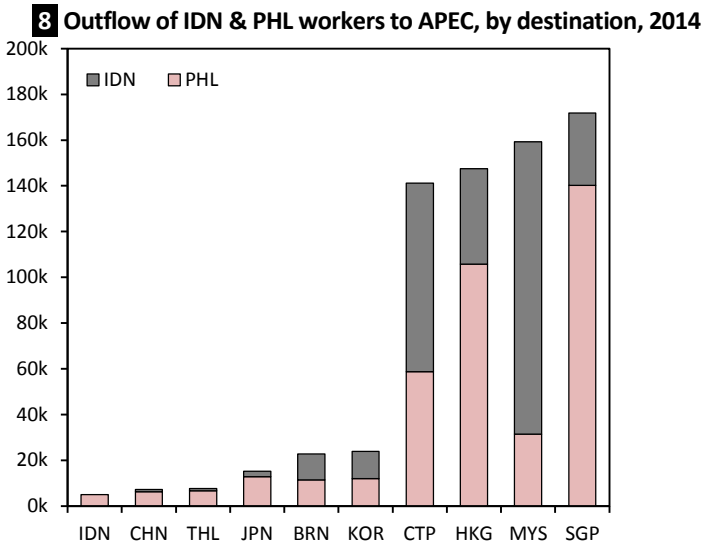
International labour and temporary migration data is scarce, of poor quality and rarely comparable. Where data does exist, it suggests that such migration is significant. For example, based on national sources (ADBI et al. 2016; Commonwealth of Australia 2015b), the stock of foreign workers is about 1.3m or a

[11] Caution should be used when comparing data and figures in sections 3.3 and 3.4. That is, these are based on different sources and definitions and it is possible that some people will be counted as both temporary / foreign workers and as permanent migrants if their stay is longer than a specified period. Modelling presented in this paper uses resident population estimates and projections to avoid errors of double-counting.

quarter of the population in Singapore, 2.3m or 8% of population in Malaysia, and 0.5m or 2% of the population in Australia (excluding New Zealand nationals). Different economies require foreign workers for different sectors and industries. For example, a third of foreign labour in Malaysia is employed in manufacturing, while the single most popular industry for foreign labour in Singapore is construction (27%), followed by domestic work (16%).

What about year-to-year flows of labour? Figure 7 presents trends based on gross outflows of workers from selected source countries. Philippines, Indonesia, and China are among the largest sources of labour migration, though Indonesia has seen declines in recent years. As shown in Figure 8, large numbers of people from the Philippines and Indonesia work in selected APEC economies, including Singapore, Malaysia, and Hong Kong. But countries in the Middle-East have been more successful in attracting temporary workers from APEC – almost a million Filipinos sought work there in 2014.





Source: Authors' analysis of ADBI et al. (2016). Figure 7 data includes outflows to all world, including APEC. Figure 8 outflows are from Indonesia and Philippines to selected APEC destinations in Asia only.

3.5. Student flows: Source of revenue and skilled labour

We also know that APEC has large numbers of expatriates studying in other member economies, many of whom return home with both academic and work experience. The US, Australia, and Japan are the most common destinations, with a 2010 to 2014 average annual inflow of students of about 400,000, 175,000, and 127,000 respectively. Where students have a route to staying permanently or at least temporarily for work, they can contribute to keeping the destination economy younger and more productive.

3.6. The promise of greater migration flows: Modelled results

So to what extent can permanent and temporary migrants offset demographic headwinds? Our modelling gives a sense of the labour force and economic impacts of several migration scenarios.

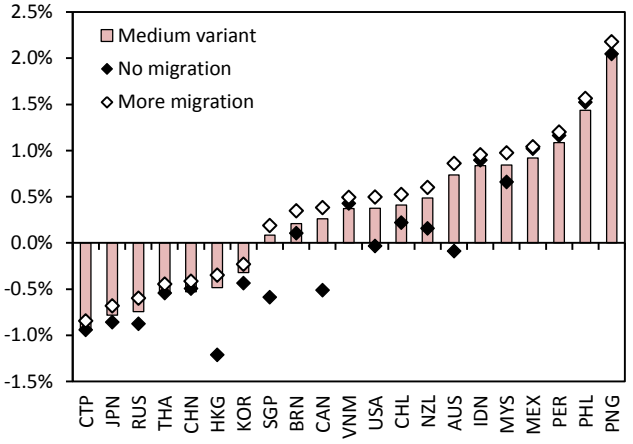
Firstly, we enumerate the value of existing permanent migration flows. This is helpful in understanding the potential impact of restricting current permanent migration (as proposed in some APEC economies). Unsurprisingly, a 'no migration' scenario would be most detrimental to economies that enjoy the greatest net inflows. For example, continued permanent net inflows into top destinations like Hong Kong and Singapore, labelled as the 'medium variant' scenario, is projected to contribute between 0.7pp and 0.8pp to annual labour force and economic growth between 2015 and 2050 compared to a 'no migration'

scenario (Figures 9 and 10). In fact, as shown in Figure 9, a lack of migrants over the next 35 years would see stagnating labour forces in Australia and the US; Singapore and Canada would join the seven countries that are already projected to see absolute declines in the numbers of workers (i.e., China, Hong Kong, Japan, Korea, Russia, Thailand, and Chinese Taipei). And Hong Kong's labour force would contract more than twice as fast as the main (median variant) projections. The modelling suggests that this would affect real GDP growth, as shown in Figure 10. For example, Hong Kong's economy would be expected to stagnate, and Singapore and Canada's would grow at half rate of the main projection.

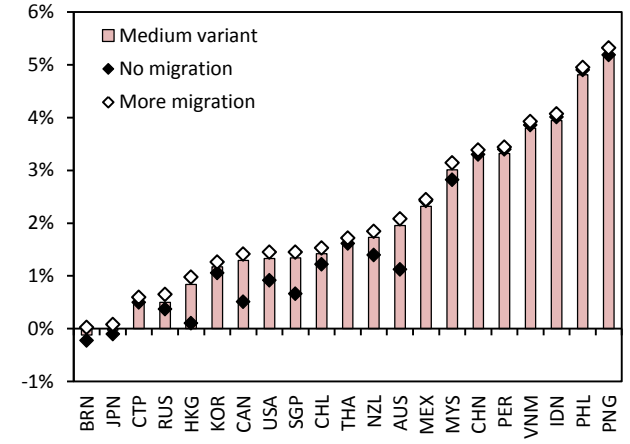
A second modelled scenario considers the effect of attracting more temporary workers aged 25-44. Here we assume conservatively that this population group would by 2050 be 10% larger than it would otherwise have been in the 'medium scenario'. So the increase is phased in very gradually over 35 years and, since it is a proportion, it depends on numbers of young people in each economy. The population group is not assumed to remain and age within the destination country but rather be replaced by new cohorts of younger people.

The results suggest such a scenario contributes positively to the growth of labour forces and GDP by about 0.09pp and 0.15pp per year over the projection period. If such a change were implemented immediately (i.e., representing a steady state of 10% more youth), it could increase an economy's total GDP by between 3% and 6% (not shown in charts). Of course, these changes are modelled mechanically and may underestimate the extra benefit of productivity gains from migration, as discussed in section 5. Also, competition for migrant labour as well as for students can stimulate development as employers and educational institutions vie for top talent.

9 **LF growth by migration scenario, 2015-2050** (% p.a.)



10 **GDP growth by migration scenario, 2015-2050** (% p.a.)



Source: Authors' analysis. Note: Participation rates by age and sex across scenarios are held constant at 2015 levels to isolate effect of migration. 'More migration' scenario represents more temporary migration of people age 25-44. Productivity growth is assumed to converge in all scenarios.

Policy levers that increase migration can direct prime-age workers to where they are most needed. But increasing numbers of working-age people is only one lever. Measures that put them to work are also needed to ensure the demographic effect translates to an economic one. So the different levers should be considered complementary.

4. PARTICIPATION

Ratios and numbers of older people and working age people only tell part of the story. To explicitly link demography to the real economy requires us to take account of the actual labour force participation, production and fiscal dependency of different groups within an economy.

4.1. Distinguishing age dependency from economic dependency

Chomik et al (2016) analysed a number of dependency measures that incorporate non-demographic factors for a range of Asian economies (including measuring dependency related to labour markets, health, long term care, and fiscal policy). They constructed a labour market economic dependency ratio where age-specific employment rates were used to weigh an economy's current and projected demographic age structure. It helped to determine the relative size of the economically dependent and non-dependent populations.[12] They found, for example, that unlike most other Asian economies, Chinese Taipei had considerably higher levels of dependency measured on this basis compared to a standard demographic measure (where the population aged 65+ is divided by the population aged 15-64). This was because of low employment rates of older people combined with a fast growing older population – a combination it can ill afford. Economies with high rates of employment among older people, such as Korea, Philippines and Thailand saw some of the dependency effects of ageing offset.

So active labour market policies and those related to retirement are important when considering the impact of population ageing. Indeed, beside new migrants (discussed in the previous section), older people and women are potential but under-utilised sources of workers, as discussed next.

4.2. Older workers: Increasing participation and future potential

The historic and projected rates of labour force participation of mature-age workers are shown in Figure 11. All APEC economies, except Brunei and Chinese Taipei, have seen increases in the rates of work of older people (aged 50-64) since 1990. New Zealand, Peru, Singapore, and Chile saw the greatest increases of over 20pp. Indeed, New Zealand currently leads APEC in its mature-age labour force participation rates of 82%.

What about the future? The central, ILO-based projection modelled in this paper, labelled in Figure 11 as 'trend increase', sees older people remaining in the labour force for longer across most of the region between 2015 and 2050. The greatest increases, of between 6pp and 8pp, are projected for Hong Kong, Brunei, and Canada.

4.3. Dismantling barriers and incentives to retire early

Such optimistic modelling relies heavily on recent trends and judgement. Higher mature-age labour force participation requires a number of policy interventions. This includes addressing barriers and incentives related to health and caring, workplace flexibility and adjustments, skills and training, and those imposed by laws, tax-benefit systems, discrimination and social norms (Chomik and Piggott 2012).

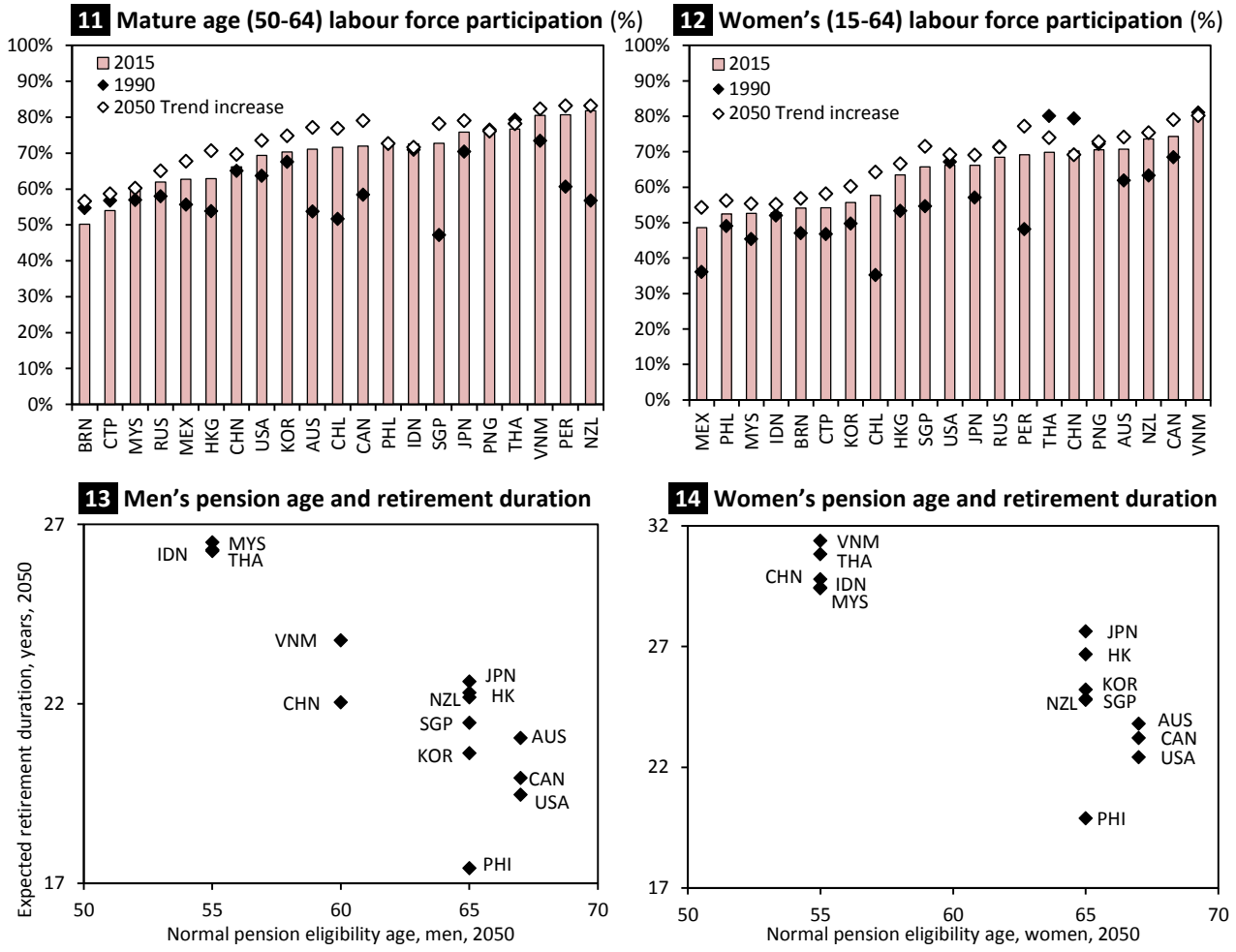
Take health barriers and pension incentives.[13] Own and family health issues comprise one of the most significant impediments to work, requiring policy that targets chronic and avoidable degenerative diseases. Unsurprisingly, healthy and mature-age life expectancy tend to be lower in less developed APEC economies. For example, in PNG, women's current (period) life expectancy at age 60 is only about 17 years, compared to Japan's 29 years (UN 2015). In PNG, women can expect 10 years of ill health toward the end of life, whereas Japanese women can expect only 9 (IHME 2013).

[12] The European Commission (e.g., EC 2014) routinely projects economic dependency based on labour force status, dividing those inactive at different ages by those in employment.

[13] See Chomik (2013a and 2013b), Chomik and Piggott (2015), and Chomik (2016) for overview and analyses of Asia's pension and healthcare systems in the context of population ageing.

Another important area relates to pension incentives, which are shown to have a strong effect on retirement decisions in advanced economies (Gruber and Wise 1999). In fact, APEC economies with the largest increases in mature-age participation between 1990 and 2015 all implemented increases in pension eligibility ages (either just for women or for both sexes).

Most advanced economies have reversed the long term trend of declining pension eligibility ages (Whitehouse and Chomik 2010). But in APEC, as health improves and life expectancies increase, some members are reluctant to set higher pension ages. As shown in Figures 13 and 14, even taking account of lower expected life expectancies, economies such as Indonesia, Malaysia, and Thailand are leaving the eligibility for their main pension schemes unchanged. Admittedly, in some APEC economies either pension coverage of the population is low, the benefits are low, or both (Chomik, 2016). Yet several countries have succeeded in expanding their pension programmes (e.g., China, and Thailand). As such schemes expand to cover more people, longer expected durations in retirement will become of increasing concern – in some cases over 25 years for men and over 30 years for women – with negative impacts on government budgets and economic growth. Signs of this trend are already visible in places like China (Giles et al. 2011). Disparity between men and women's pension ages is especially perplexing since women tend live longer, healthier lives then men (IHME 2013). Gendered pension ages often result in lower benefits and greater levels of poverty for older women.



Source: Authors' analysis and OECD (2013)

4.4. Women: Enabling formal employment

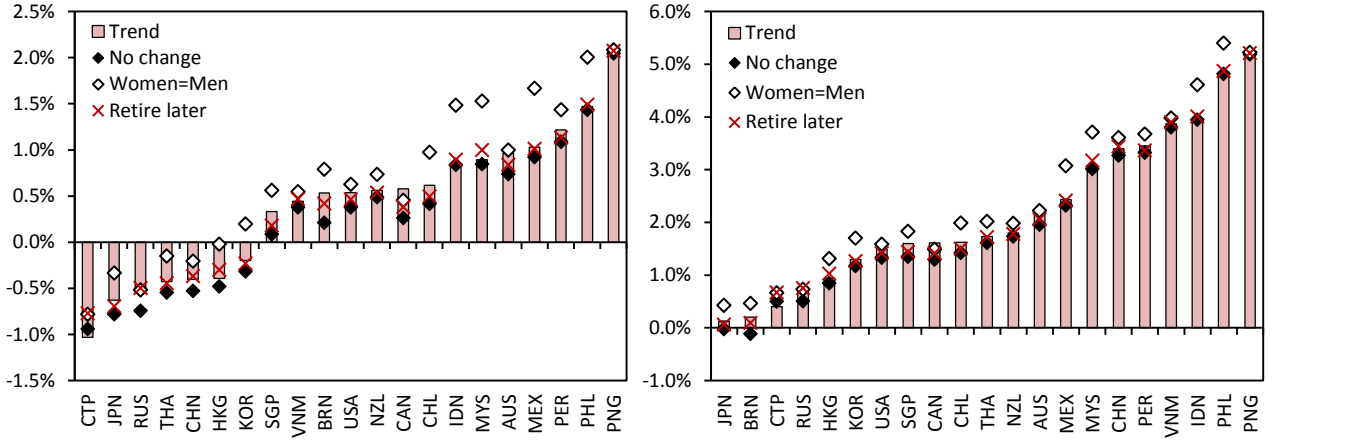
Since 1990, most economies saw increases in total participation of women (Figure 12). Thailand and China are notable exceptions, but declines there were from a high level. As flagged in section 2, trends in China and Thailand were related to decreasing participation of young women – likely as a result of higher enrolment in education – and some decreases in participation of older women. The greatest increases were seen in Peru, Chile, and Mexico, but in each case these were from a low base. Currently the highest rates of women's participation are seen in Vietnam, Canada, and New Zealand.

By 2050 it is expected that women's total and most age-specific labour force participation rates will increase, as shown in Figure 12.[14] But these trends presuppose policies that encourage women to work. Developed country experience suggests that these policies include flexible work-time arrangements, tax systems that don't penalise second earners, institutions that don't discriminate and encourage equal wages, and support of families with elderly needing care and young children –indeed childcare services are one of the strongest factors affecting the labour force participation of women (Thevenon 2013).

4.5. The promise of higher participation rates: Modelled results

So to what extent would the projections differ under different policy outcomes? To isolate the effects of higher participation rates among older people and women we present several scenarios. These are shown in Figures 15 and 16, comparing the annual labour force and GDP growth under scenarios with: (1) no change to participation rates; (2) trend increase (as used in main results); (3) delayed retirement (where each 5-year age group between 50 and 64 assume the participation rate of the next, younger group); and (4) a scenario in which women end up participating in the formal market at the same rate as men do in 2015 (even as men's rates remain constant). All changes are gradually phased in over the next 35 years.

15 LF growth by participation scenario, 2015-2050 (% p.a.) **16 GDP growth by participation scenario, 2015-2050** (% p.a.)



Source: Authors' analysis. Note: Population assumptions are based on medium variant. Productivity is assumed to converge.

A lack of progress on labour force participation would likely mean lower labour force and GDP growth. That is, growth in these indicators would be dragged down by about 0.1pp per year for the average APEC economy compared to the 'trend increase' scenario. While delaying retirement has a positive effect, equalising the participation rates of men and women has the greatest impact, especially for countries with higher gender disparities, such as Malaysia and Mexico. For example, if by 2050, Mexican women

[14] Note that rates of projected unemployment are also based on ILO data, which assumes a reversion to long term rates (i.e. consistent with long term 'full employment').

participated in the labour market at the same rate as men do now, labour force and GDP would grow 0.7pp and 0.8pp faster than if rates stayed at the 2015 level.

It's interesting to note that the 'retire later' scenario presented here and the extra migration scenario presented in section 3.6 have similar impacts. That is, greater temporary migration in each economy can increase the labour force as much as delaying retirement by five years. Of course, such effects can reinforce each other and should be viewed as complementary.[15]

5. PRODUCTIVITY

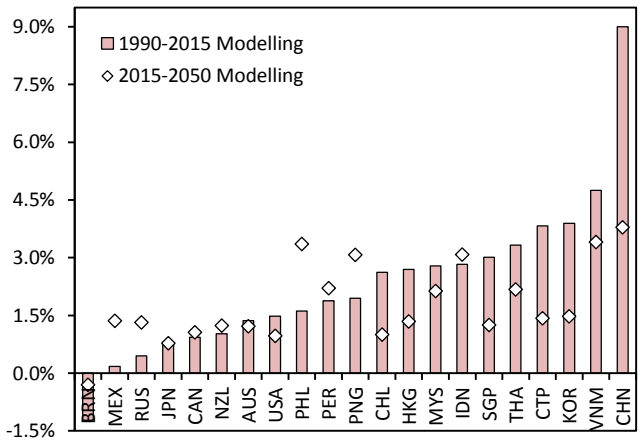
As the final P in the 3P framework, productivity is a somewhat *catch-all* category. Here it is defined as the average amount of output (GDP) per unit of input (labour).

5.1. Convergence as a working assumption

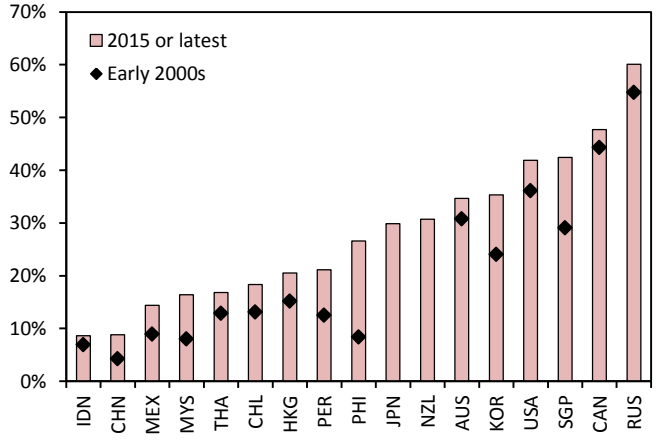
Since we know the total GDP and the number of workers in each APEC economy in each year since 1990, we can easily derive the levels of productivity and how these have changed over time. As shown in Figure 17, productivity growth between 1990 and 2015 was positive in all APEC economies except Brunei. The unweighted average productivity growth for the region was 2.3% per annum, with China, Vietnam, and Korea seeing the greatest gains.

Modelling for 2015 to 2050 assumes convergence of productivity growth. Each group of economies by level of income/industrialisation end up with the productivity growth seen in the group of economies with the next highest income group in the last 25 years (see Appendix B). The implicit assumption, based on economic theory and empirical research, is that lower income economies have the greatest potential to catch up but that as they develop it becomes more difficult to reap additional benefits of technological advancement and overcome development constraints such as urbanisation and formalisation (Baumol 1986; Barro 1997).[16] Convergence requires technological knowledge to flow across borders via a combination of foreign direct investment, transfers of codified knowledge, and movement of individuals. Each requires attention to ensure continued productivity improvements.

17 Productivity growth (% change in GDP per worker p.a.)



18 Tertiary educational attainment (% of 25+ pop)



Sources: Authors' analysis of ILO (2015a) and UIS (2017)

[15] It is worth emphasising that immigrants or workers who delay retirement are not reducing work opportunities for others in the medium term. The widespread notion that people working longer will in general displace youth employment is effectively countered in various places. For example, countries with higher mature-age employment also have higher youth employment (OECD 2012; also see detailed evidence in Gruber and Wise, 2010).

[16] Convergence also presupposes adequate capital investments and institutions to take advantage of development potential.

The rate of productivity improvement in each economy is also influenced here by the point of departure for the projection (modelled as the average change over the last three years). In the model, these assumptions translate to drops in productivity growth in most economies by 2050. Those expecting significant productivity improvements include PNG, Philippines, Russia, and Mexico, and to a lesser extent Indonesia, Peru and New Zealand. But the region's overall, unweighted average over the next 35 years is expected to drop to 1.8% per annum.

As each economy's population ages and labour force growth decelerates or turns negative, the case for investing in the productivity of the remaining labour force strengthens. It is also a direct way to increase standards of living as measured by GDP per capita. Productivity gains result from how well labour inputs combine with physical capital and technology. Here we highlight the investment in human capital and formalisation, which turn out to be mutually reinforcing.

5.2. Education: Investing in smaller workforces

Human capital refers mainly to health (mentioned earlier) and education. An abundance of well-educated people goes hand in hand with a high level of labour productivity, particularly where skills match opportunities. It also implies a greater ability to absorb advanced technology from developed economies and investments in physical capital.

The level and distribution of educational attainment also have an impact on social outcomes, such as child mortality, fertility, and the distribution of income. A number of these factors are endogenous and reinforcing. For example, lower fertility rates mean societies can invest more in fewer children – a pattern observed in the Asia Pacific and elsewhere (Mason and Lee 2011).

Educational levels have increased across APEC. For example, as shown in Figure 18, all economies for which data exists have seen increases in the proportion of people with tertiary education, a measure of education that is probably more relevant for later stages of development. The greatest increases were seen in Philippines, Korea and Singapore. Those with the highest levels of tertiary education attainment include Russia, Canada, and Singapore. In fact, Singapore's success in education policy can act as a good example for policy-makers across the region, including advanced economies. Lessons include building teacher capacity, ambitious standards and assessments; and continuous improvement by benchmarking of outcomes and practice (OECD 2011, 2014).

But as with health, investment in skills should be encouraged over the life course. Structural change in the economy (see below) means it's important to retrain older workers. For example, between 1990 and 2013, employment in routine occupations in the US fell by about 30%, taking millions of jobs (Siu and Jaimovich 2015). Research in advanced economies suggests that creating opportunities, dismantling barriers and encouraging a culture of continuous learning are important (OECD 2014b).

As cyclical and structural changes unfold, importing labour may be a way to address local gaps in the supply of specific skills. In fact, changes to migration flows, particularly for temporary workers between countries with appropriate labour mobility agreements, is driven by favourable economic circumstances in the destination country. But labour migration can result in matching skills to jobs in the short term as well as to improve the exchange of knowledge and technology, and ultimately productivity, in the medium term. For example, labour mobility benefits source countries by (1) strengthening international trade and investment relationships, increasing access to capital and new ways of working; (2) sending home money

that contributes to poverty reduction, domestic investment and expansion of financial services (e.g., In 2013, remittances were worth 10% of GDP in the Philippines)[17]; and (3) providing entrepreneurship, technology, and capital resources when they return (World Bank 2008).

5.3. The route to formality: Enabling structural change and the capacity of entrepreneurs

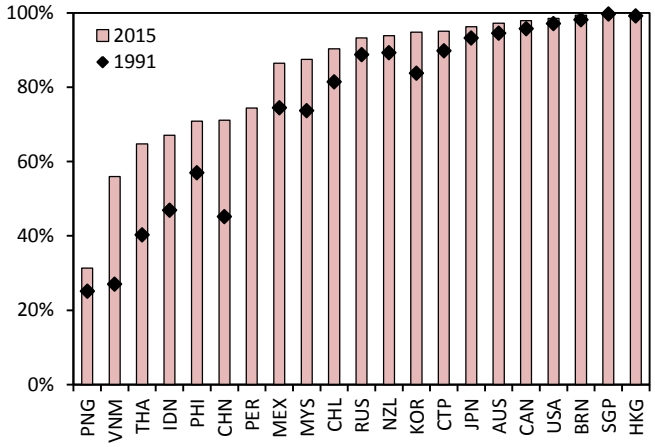
One of the greatest engines of growth in APEC has been the productivity-enhancing movement of workers *from farm to factory*. This was particularly the case in China, where the non-agricultural sector's share of employment increased from 45% in 1991 to 71% in 2015 (Figure 19). This structural transition typically shifts economic activity from agriculture, to manufacturing, to services.

Yet in many APEC economies, informality in the non-agricultural sector still holds back productivity improvements. Jobs in the informal sector tend to be for very small and inefficient firms, with limited access to financing and technology, producing low-cost low-quality output for low-income consumers, and run by poorly educated entrepreneurs (La Porta and Shleifer 2014).

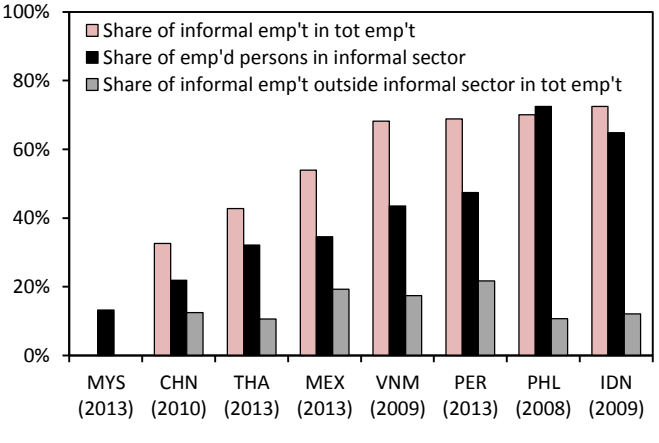
The informal economy's share of employment includes jobs in informal firms and jobs in formal firms with informal contracts. As shown in Figure 20, the former is more significant. Upper middle-income economies such as Malaysia and China tend to have lower informal employment than lower middle-income economies such as Indonesia and Philippines. In fact, the proportion of total employment in the informal economy in Indonesia was estimated to be as high as 73% in 2009.

A key insight from research is that the education of managers is a key driver to formalisation, since transitioning to the formal sector has no pay-off for a firm unless it can be as efficient as one run by an educated entrepreneur (La Porta and Shleifer 2008, 2014; Gennaioli et al 2013). Formalisation tends to take place as formal firms grow in size and take on new cohorts of workers while small, informal firms go out of business. Again, this process can be inhibited by low managerial education.

19 Employment in non-agricultural sector (% of tot emp)



20 Informal employment (% of non-agricultural sector)



Sources: Authors' analysis of ILO (2015a)

But total rates of formalisation may only decline if the formal sector absorbs potential workers faster than the demographic processes of internal migration and high fertility supply them. For example, La Porta and Shleifer (2014) suggest that comparing the growth rates of the labour force and GDP per capita can be revealing about whether rates of informal employment change (as proxied by self-employment).

[17] see ADBI et al 2016; Imai et al 2014

Between 1990 and 2015, economies such as China and Korea saw labour forces grow at only about 14% and 46% of the growth in GDP per capita, respectively. During this time they also experienced large declines in self-employment as share of total employment, of 34pp and 11pp. By contrast, Chile and Peru's labour forces grew almost as fast as GDP per capita (at 73% and 91% of the growth of GDP per capita). This was associated with respective declines in self-employment of only 4% and 5%.

6. CONCLUDING DISCUSSION

The preceding analysis and attempted to elucidate the connection between the population age structure, labour force participation, and productivity, and their combined impacts on economic activity.

6.1. Declining economic and labour force growth pose new challenges

The central projection is that, between 2015 and 2050, declines in the size of labour forces are expected in China, Hong Kong, Japan, Korea, Russia, Thailand, and Chinese Taipei. A deceleration in the growth of labour forces is expected in other economies. And only Mexico, Peru, Philippines, and Papua New Guinea are projected to see labour forces grow at above 1% per annum over the next 35 years.

This will have profound effects on economic growth, with average GDP growth declining from an unweighted average of 4.1% per annum between 1990 and 2015, to 2.2% between 2015 and 2050. China, for instance, is expected to grow at a modest 3.4% per annum over the next 35 years, compared to about 10% over the last 25. Those projected to grow fastest, with rates of 4% or above, include Indonesia, Philippines, and Papua New Guinea. Average growth in the standards of living in APEC, as measured by GDP per capita, is also expected to slow.

Several scenario analyses showed that attracting permanent or temporary migrants or increasing participation rates of older workers or women can benefit economic activity and standards of living and partly offset some of the economic headwinds created by population ageing.

6.2. Policy responses to meet the new challenges

In summary, various policy levers can affect the 3Ps that drive future welfare. Such policies are complementary responses to population ageing; all should be on the table if APEC is to meet the demographic challenges ahead.

***Population*:** Modelling suggests that a migration program focused on younger workers will enhance labour force, GDP, and GDP per capita growth. Those jurisdictions that find inward migration acceptable and where institutions are in place to attract and take full advantage of both temporary and permanent migrants may be able to offset some of the effects of population ageing. Indeed, conservative increases in temporary migration are modelled to be as effective as delaying retirement in the native population – currently one of the most common policy responses to ageing labour forces. Demographic differences within APEC can offer synergies within the block: youthful populations in places with few jobs and low productivity can move to places with high labour demand and productivity. The process could potentially tap productive capacity of the region as has been the case with internal migration to cities.

***Participation*:** Encouraging mature age labour force participation will depend on how well economies address barriers and incentives related to health and caring, workplace flexibility and adjustments, skills and training, and those imposed by laws (e.g., age discrimination), tax-benefit systems, and social norms.

One obvious policy lever relates to pensions, and their access age. As we mention above, APEC economies which have enjoyed the most significant increases in mature labour force participation have increased access age for retirement benefits. Encouraging female labour force participation will depend on policies that allow flexible work-time arrangements, taxation systems that don't penalise second earners, institutions and laws that don't discriminate and encourage equal wages, and support of families with young children – particularly childcare services. At a more subtle level, social expectations play a role in both female and mature labour force participation. In many economies, women are now expected to play a role in the labour market, which was not the case a generation ago. Modifying expectations is a slow process but is of great importance.

***Productivity*:** Labour productivity is affected by health status, education, and formalisation. Improvement in any of these will likely increase productivity. Education and health provision should be seen as investments rather than consumption expenditure. As we pointed out above, there is evidence to suggest that formalisation is facilitated through better educated managers and entrepreneurs. Also important are institutional sophistication, good infrastructure and strong governance (Piggott and Sane 2012). Here too migration could play a role by stimulating knowledge exchange via cross-border movements of people.

International cooperation: How can international institutions such as APEC help? Simplifying migration and building capacity in the related institutions between APEC economies would be a constructive step. Or consider education. APEC economies are well connected with regard to international education. Economies such as the US, Japan and Australia have large student cohorts from a range of APEC economies. Simplifying the process of deciding whether students met specified criteria, and also visas and associated documentation, would be helpful. Simply abolishing visa fees for APEC citizens would be a positive step. Similarly, some advanced APEC economies are in a position to assist capacity building around the development and implementation of appropriate financial and legal governance structures. Investment and trade negotiations could be promoted to facilitate technology dissemination, an important driver of productivity growth. Cooperation will be critical to create synergies between economies that are ageing and developing at different rates, allowing APEC to meet the challenges of an ageing century.

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APPENDIX A. PROJECTION RESULTS BY SCENARIO, 2015-2050

	Scenarios			Effects			
	Population numbers by age	Participation rates by age	Productivity growth	Share of 15-64 in population: average annual change, 2015-2050	Total labour force: average annual change, 2015-2050	GDP/capita: average real growth, 2015-2050	GDP: average real growth, 2015-2050
AUS	Medium	No change	Convergence	-0.27%	0.74%	0.98%	1.95%
	No migration	No change	Convergence	-0.42%	-0.09%	0.88%	1.12%
	More migration	No change	Convergence	-0.22%	0.86%	1.04%	2.08%
	Medium	Retire later	Convergence	-0.27%	0.84%	1.09%	2.06%
	Medium	Women=Men2015	Convergence	-0.27%	1.00%	1.25%	2.22%
	Medium	Trend increase	Convergence	-0.27%	0.96%	1.21%	2.19%
BRN	Medium	No change	Convergence	-0.49%	0.21%	-0.84%	-0.12%
	No migration	No change	Convergence	-0.51%	0.10%	-0.86%	-0.22%
	More migration	No change	Convergence	-0.45%	0.35%	-0.77%	0.02%
	Medium	Retire later	Convergence	-0.49%	0.42%	-0.63%	0.09%
	Medium	Women=Men2015	Convergence	-0.49%	0.79%	-0.27%	0.46%
	Medium	Trend increase	Convergence	-0.49%	0.53%	-0.52%	0.20%
CAN	Medium	No change	Convergence	-0.41%	0.26%	0.70%	1.29%
	No migration	No change	Convergence	-0.57%	-0.51%	0.59%	0.51%
	More migration	No change	Convergence	-0.37%	0.38%	0.75%	1.41%
	Medium	Retire later	Convergence	-0.41%	0.38%	0.82%	1.41%
	Medium	Women=Men2015	Convergence	-0.41%	0.45%	0.89%	1.49%
	Medium	Trend increase	Convergence	-0.41%	0.58%	1.02%	1.61%
CHL	Medium	No change	Convergence	-0.42%	0.41%	0.88%	1.42%
	No migration	No change	Convergence	-0.47%	0.22%	0.84%	1.22%
	More migration	No change	Convergence	-0.37%	0.52%	0.93%	1.53%
	Medium	Retire later	Convergence	-0.42%	0.49%	0.96%	1.50%
	Medium	Women=Men2015	Convergence	-0.42%	0.97%	1.44%	1.98%
	Medium	Trend increase	Convergence	-0.42%	0.62%	1.09%	1.63%
CHN	Medium	No change	Convergence	-0.62%	-0.53%	3.32%	3.27%
	No migration	No change	Convergence	-0.61%	-0.50%	3.33%	3.30%
	More migration	No change	Convergence	-0.57%	-0.42%	3.38%	3.39%
	Medium	Retire later	Convergence	-0.62%	-0.37%	3.49%	3.43%
	Medium	Women=Men2015	Convergence	-0.62%	-0.21%	3.66%	3.60%
	Medium	Trend increase	Convergence	-0.62%	-0.40%	3.46%	3.40%
HKG	Medium	No change	Convergence	-0.89%	-0.48%	0.52%	0.84%
	No migration	No change	Convergence	-1.11%	-1.21%	0.31%	0.10%
	More migration	No change	Convergence	-0.83%	-0.35%	0.59%	0.97%
	Medium	Retire later	Convergence	-0.89%	-0.30%	0.70%	1.03%
	Medium	Women=Men2015	Convergence	-0.89%	-0.02%	0.99%	1.31%
	Medium	Trend increase	Convergence	-0.89%	-0.39%	0.61%	0.94%
IDN	Medium	No change	Convergence	-0.05%	0.84%	3.28%	3.95%
	No migration	No change	Convergence	-0.04%	0.90%	3.28%	4.01%
	More migration	No change	Convergence	-0.01%	0.95%	3.32%	4.07%
	Medium	Retire later	Convergence	-0.05%	0.89%	3.34%	4.00%
	Medium	Women=Men2015	Convergence	-0.05%	1.48%	3.94%	4.61%
	Medium	Trend increase	Convergence	-0.05%	0.84%	3.29%	3.96%
JPN	Medium	No change	Convergence	-0.49%	-0.78%	0.44%	-0.03%
	No migration	No change	Convergence	-0.51%	-0.86%	0.43%	-0.10%
	More migration	No change	Convergence	-0.43%	-0.68%	0.49%	0.08%
	Medium	Retire later	Convergence	-0.49%	-0.70%	0.53%	0.06%
	Medium	Women=Men2015	Convergence	-0.49%	-0.34%	0.90%	0.43%
	Medium	Trend increase	Convergence	-0.49%	-0.63%	0.60%	0.13%
KOR	Medium	No change	Convergence	-0.88%	-0.32%	1.15%	1.17%
	No migration	No change	Convergence	-0.92%	-0.44%	1.14%	1.05%
	More migration	No change	Convergence	-0.84%	-0.23%	1.19%	1.26%
	Medium	Retire later	Convergence	-0.88%	-0.23%	1.24%	1.26%
	Medium	Women=Men2015	Convergence	-0.88%	0.20%	1.68%	1.70%
	Medium	Trend increase	Convergence	-0.88%	-0.20%	1.28%	1.30%
MEX	Medium	No change	Convergence	-0.07%	0.92%	1.58%	2.32%
	No migration	No change	Convergence	-0.06%	1.02%	1.59%	2.42%
	More migration	No change	Convergence	-0.03%	1.04%	1.63%	2.44%
	Medium	Retire later	Convergence	-0.07%	1.01%	1.67%	2.41%
	Medium	Women=Men2015	Convergence	-0.07%	1.67%	2.33%	3.07%
	Medium	Trend increase	Convergence	-0.07%	1.03%	1.69%	2.43%
MYS	Medium	No change	Convergence	-0.14%	0.85%	2.14%	3.01%
	No migration	No change	Convergence	-0.16%	0.66%	2.13%	2.82%
	More migration	No change	Convergence	-0.10%	0.97%	2.20%	3.14%
	Medium	Retire later	Convergence	-0.14%	1.00%	2.30%	3.17%
	Medium	Women=Men2015	Convergence	-0.14%	1.53%	2.84%	3.71%
	Medium	Trend increase	Convergence	-0.14%	0.89%	2.20%	3.06%
NZL	Medium	No change	Convergence	-0.26%	0.49%	1.11%	1.73%
	No migration	No change	Convergence	-0.31%	0.16%	1.09%	1.39%
	More migration	No change	Convergence	-0.22%	0.60%	1.15%	1.84%
	Medium	Retire later	Convergence	-0.26%	0.53%	1.16%	1.78%
	Medium	Women=Men2015	Convergence	-0.26%	0.73%	1.36%	1.98%
	Medium	Trend increase	Convergence	-0.26%	0.56%	1.18%	1.80%

PER	Medium	No change	Convergence	-0.05%	1.09%	2.47%	3.32%
	No migration	No change	Convergence	-0.04%	1.16%	2.47%	3.40%
	More migration	No change	Convergence	-0.01%	1.20%	2.51%	3.44%
	Medium	Retire later	Convergence	-0.05%	1.13%	2.51%	3.37%
	Medium	Women=Men2015	Convergence	-0.05%	1.43%	2.82%	3.67%
	Medium	Trend increase	Convergence	-0.05%	1.22%	2.60%	3.45%
PHL	Medium	No change	Convergence	0.14%	1.44%	3.66%	4.81%
	No migration	No change	Convergence	0.14%	1.52%	3.66%	4.90%
	More migration	No change	Convergence	0.18%	1.56%	3.71%	4.95%
	Medium	Retire later	Convergence	0.14%	1.49%	3.72%	4.87%
	Medium	Women=Men2015	Convergence	0.14%	2.00%	4.24%	5.40%
	Medium	Trend increase	Convergence	0.14%	1.47%	3.70%	4.85%
PNG	Medium	No change	Convergence	0.27%	2.05%	3.53%	5.18%
	No migration	No change	Convergence	0.27%	2.05%	3.53%	5.18%
	More migration	No change	Convergence	0.32%	2.18%	3.58%	5.32%
	Medium	Retire later	Convergence	0.27%	2.07%	3.56%	5.21%
	Medium	Women=Men2015	Convergence	0.27%	2.08%	3.57%	5.22%
	Medium	Trend increase	Convergence	0.27%	2.10%	3.59%	5.24%
RUS	Medium	No change	Convergence	-0.37%	-0.75%	0.82%	0.50%
	No migration	No change	Convergence	-0.39%	-0.88%	0.79%	0.37%
	More migration	No change	Convergence	-0.32%	-0.60%	0.89%	0.65%
	Medium	Retire later	Convergence	-0.37%	-0.50%	1.07%	0.75%
	Medium	Women=Men2015	Convergence	-0.37%	-0.52%	1.05%	0.73%
	Medium	Trend increase	Convergence	-0.37%	-0.55%	1.02%	0.70%
SGP	Medium	No change	Convergence	-0.79%	0.08%	0.84%	1.34%
	No migration	No change	Convergence	-0.91%	-0.59%	0.78%	0.66%
	More migration	No change	Convergence	-0.75%	0.19%	0.88%	1.45%
	Medium	Retire later	Convergence	-0.79%	0.18%	0.93%	1.44%
	Medium	Women=Men2015	Convergence	-0.79%	0.56%	1.32%	1.83%
	Medium	Trend increase	Convergence	-0.79%	0.33%	1.09%	1.60%
THA	Medium	No change	Convergence	-0.65%	-0.55%	1.86%	1.61%
	No migration	No change	Convergence	-0.63%	-0.54%	1.86%	1.61%
	More migration	No change	Convergence	-0.60%	-0.45%	1.90%	1.71%
	Medium	Retire later	Convergence	-0.65%	-0.44%	1.96%	1.72%
	Medium	Women=Men2015	Convergence	-0.65%	-0.15%	2.26%	2.02%
	Medium	Trend increase	Convergence	-0.65%	-0.43%	1.98%	1.73%
CTP	Medium	No change	Convergence	-0.98%	-0.94%	0.83%	0.49%
	No migration	No change	Convergence	-0.98%	-0.94%	0.83%	0.49%
	More migration	No change	Convergence	-0.94%	-0.85%	0.88%	0.59%
	Medium	Retire later	Convergence	-0.98%	-0.77%	1.01%	0.67%
	Medium	Women=Men2015	Convergence	-0.98%	-0.78%	1.00%	0.66%
	Medium	Trend increase	Convergence	-0.98%	-1.03%	0.74%	0.41%
USA	Medium	No change	Convergence	-0.27%	0.37%	0.78%	1.33%
	No migration	No change	Convergence	-0.33%	-0.03%	0.75%	0.92%
	More migration	No change	Convergence	-0.22%	0.49%	0.83%	1.45%
	Medium	Retire later	Convergence	-0.27%	0.46%	0.87%	1.42%
	Medium	Women=Men2015	Convergence	-0.27%	0.62%	1.03%	1.58%
	Medium	Trend increase	Convergence	-0.27%	0.54%	0.94%	1.49%
VNM	Medium	No change	Convergence	-0.37%	0.37%	3.24%	3.80%
	No migration	No change	Convergence	-0.36%	0.43%	3.25%	3.85%
	More migration	No change	Convergence	-0.32%	0.49%	3.29%	3.92%
	Medium	Retire later	Convergence	-0.37%	0.47%	3.34%	3.90%
	Medium	Women=Men2015	Convergence	-0.37%	0.55%	3.42%	3.98%
	Medium	Trend increase	Convergence	-0.37%	0.44%	3.31%	3.87%

Source: Authors calculations. Note: See scenario explanations below.

- *Medium population, No participation change*: This is the 'no change' scenario, it does not incorporate changes to migration or participation rates.
- *No migration scenario*: Makes use of the UN (2015) 'zero migration' population variant.
- *More migration*: Population aged 25-44 in each year between 2015 and 2050 is increasingly higher than it would have been in the 'medium' variant, so that by 2050 there are 10% more people of that age than there would otherwise have been. Labour force profiles are the same as local population. No account is taken of those extra people remaining in the jurisdiction and having children etc. This effectively models temporary migration.
- *Retire later*: Each 5-year age group between 50 and 64 sees a gradual increase in participation between 2015 and 2050, reaching rates seen in 2015 for group aged 5 years younger. For example, 50-54-year-olds end up with the participation rates now seen among 45-49-year-olds. Rates of all other age groups remain at 2015 levels.
- *Women equal men*: Gradual increase in women's participation rates between 2015 and 2050, reaching rates seen in 2015 for men. Rates for men remain at 2015 levels.
- *Central projection*: Discussed in most of this paper. Incorporates 'medium' population variant with trend migration from UN (2015), 'Trend increase' in participation rates from ILO (2015), and 'convergence' of productivity.

APPENDIX B. MODELLING ASSUMPTIONS AND METHODOLOGY

- *The model:* Based on the product of (1) population (number by 5-year-age-group and sex) based on UN (2015) for historic and central projection and on authors' assumptions for certain scenarios as described in Appendix A; (2) labour force participation (rate by 5-year-age-group and sex), based on ILO (2015) for historic and central projection and on authors' assumptions for certain scenarios as described in Appendix A; (3) unemployment (rate by age for ages 15-24, 25+ and sex) based on ILO (2015) for historic and central projection; and (4) productivity (real GDP per worker) based on IMF (2016) for historic and authors' assumptions for central projection as described below.
- *Decomposition method:* To see contribution, each factor is varied while others are held constant at levels observed in 1990 for 1990-2015 analysis and at 2015 for the 2015-2050 analysis. That is, we independently vary either (1) the number of people in each age group; (2) the rates of participation in each group; (3) the rates of unemployment in each age group; or (4) the productivity of each worker. If, for example, the number of people aged 25-29 increases but the participation of this age group is constant, the increase in production will be entirely due to population changes and none will be ascribed to participation – even though more people are participating in the labour force.
- *Decomposition and overall effects:* Since calculations include non-linear underlying changes over time and summation and multiplication of different variables (i.e., multiplication of numbers of people in age groups and rates for those age groups, which are summed and then multiplied by GDP per worker), the total effect when all variables are changed is not exactly equal to the sum or the product of the effects of variables changed independently. The decomposition is therefore based on taking the individual changes as proportions of the multiplicative change and applying those proportions to the overall change when all factors are run together.
- *Hours worked versus workers:* Note that the model ignores hours worked, so any decreases in hours would show up in increased GDP per capita. Historically average hours actually worked have reduced across APEC. That means GDP per hour worked increased faster than GDP per worker. In future, hours average hours are likely to decline since older workers work fewer hours. It is therefore unclear whether the present model under- or overestimates future GDP growth since lower expected hours may be offset by higher productivity per hour assumptions.
- *Productivity is averaged across workers:* Note that there are no differences in the model about differential production of men and women. Nor are there any other differences, e.g., education, sector, employment type. That is, each is worker is assumed to generate the average worker's level of GDP per year.
- *Convergence:* Projections assume convergence of productivity growth. Each group of economies by level of income/industrialisation end up in 2050 with the productivity growth seen in the group of economies with a higher level of income/industrialisation in the last 25 years

Historic and projected productivity growth (% change p.a.)	ACTUAL	PROJECTED	
	1990-2015 avg.	2040	2050
High income, industrialised (AUS, CAN, JPN, NZL, USA)	1.1%	1.1%	1.1%
High income, non-industrialised or recently industrialised (BRN, CHL, HKG, KOR, SGP, TWN)	2.5%	1.1%	1.1%
Upper middle income (CHN, MEX, MYS, PER, RUS, THA)	2.9%	2.5%	1.1%
Lower middle income (IDN, PHL, PNG, VNM)	2.8%	2.9%	2.5%

Source: Authors' analysis. Note: Each economy is projected to have a productivity growth that interpolates in a straight line between the average productivity growth seen in 2012 to 2015 and the levels shown in above table. Income categories are based on World Bank definitions in 2015.