Australian Government

The Treasury

LONG-TERM INTERNATIONAL GDP PROJECTIONS

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Treasury Working Paper[2]

2013-02

Date created: 18 October 2013

Date modified: 10 January 2014

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2 The views expressed in this paper are those of the authors and do not necessarily reflect those of The Australian Treasury or the Australian Government.

ISBN 978-0-642-74935-2

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ABSTRACT

This paper develops a framework for projecting the GDP growth of Australia's trading partners from 2012 to 2050. The framework draws heavily on the existing conditional growth literature, including long-standing estimates of key convergence parameters. It adds to the large amount of research in this area by providing estimates of the level of long-run relative productivity for 155 countries. We use a novel non-parametric approach that combines the World Economic Forum's ordinal measure of long-run relative productivity (the 'Global Competiveness Index') and actual observed productivity to produce a cardinal measure of long-run relative productivity.

JEL Classification Numbers: F01, O40, O50
Keywords: China, India, conditional convergence

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1. INTRODUCTION

Fiscal agencies, including the Australian Treasury, routinely make long-term projections of their respective economies to better inform policymakers on the key determinants of future economic well-being. For a small open economy, such as Australia, international trade is an important determinant of economic growth. As such, a well-thought-out projection of the long-term growth of the Australian economy must in turn consider the long-term outlook of its trading partners. This paper responds to that challenge by developing a framework for projecting the GDP growth of Australia's trading partners from 2012 to 2050.[3]

Economists have long grappled with the question of why some countries grow faster than others. The literature on growth and development is rich with theories of the determinants of economic growth. The dominant paradigm is the neo-classical growth model which assumes growth is determined in the long run by the growth of the labour force and an exogenous factor called labour-augmenting technological progress (that is, labour productivity growth net of capital deepening). This theory has been modified over time to allow the level of labour-augmenting technological progress to vary across countries according to observable characteristics identified by the vast empirical growth literature as being statistically and economically significant (see the extensive survey by Barro and Sala-i-Martin, 2004). In this sense, the convergence framework is *conditional* rather than *absolute*, as countries' steady-state (or long-run) productivities are allowed to vary depending on the individual characteristics of each country.

The projection framework adopted here draws heavily on the existing conditional growth literature, including long-standing estimates of key convergence parameters. Even with the benefit of a large amount of research in this area, it remains a challenge to determine (and compile the data for) the factors that should be used in estimating each country's long-run relative productivity. We overcome this problem by using the World Economic Forum's Global Competitiveness Index (GCI) — a single metric that attempts to capture the multitude of factors affecting a country's long-run productivity. In essence, we view the GCI as an ordinal proxy for long-run relativities in productivity between countries, and use non-parametric methods to estimate a relationship between the GCI and actual productivity. For countries away from their steady state, this estimated relationship allows us to make cardinal predictions of their long-run productivity relative to the benchmark country (which is the United States).

The remainder of the paper is organised as follows: Section 2 describes the theory underlying the empirical conditional growth model; Section 3 describes the data underlying the empirical model's parameters and long-term GDP projections; Section 4 details the methodology used in estimating key convergence parameters; Section 5 reports long-term international GDP projections; and Section 6 summarises the key findings and outlines future research projects.

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3 Long-term international GDP projections have contributed to recent Australian Government documents, including the *Australia in the Asian Century: White Paper* (see Australian Government, 2012, for details).

2. THEORY

The basic neo-classical growth model

The basic neo-classical model (Ramsey model) provides the basis for much of the empirical growth literature. This is due to its parsimony and broad consistency with observed data. In particular, Barro and Sala-i-Martin (1992) show that the near steady-state dynamics of country *i*'s output per unit of effective labour at time *t* can be approximated by the following dynamic relationship:

$$\ln(z_{it}) = e^{-\beta(t-s)} \ln(z_{is}) + (1-e^{-\beta(t-s)}) \ln(z_i^*),$$
$$z_{it} = \left(\frac{w_{it}}{x_{it}} \right), w_{it} = \left(\frac{y_{it}}{n_{it}} \right) \quad (1)$$

where at time t: y_{it} is country *i's* output, n_{it} is country *i's* labour input, w_{it} is country *i's* labour productivity, x_{it} is country *i's* level of labour-augmenting technological progress, z_{it} is country *i's* output per unit of effective labour, with an * indicating steady-state values and β is the common speed of convergence.

This implies that the per-period growth rate of labour productivity is governed by the following error correction framework:

$$\begin{aligned} \ln(w_{it} / w_{i,t-1}) &= \ln(x_{it} / x_{i,t-1}) - (1-e^{-\beta}) \left[\ln(z_{i,t-1}) - \ln(z_i^*) \right] \\ &= \ln(x_{it} / x_{i,t-1}) - (1-e^{-\beta}) \left[\ln(w_{i,t-1}) - \ln(x_{i,t-1}) - \ln(z_i^*) \right] \end{aligned} \quad (2)$$

According to this relationship, productivity growth is a function of the growth in labour-augmenting technological progress and the percentage deviation of actual output per effective labour unit from its steady-state level. Along the balanced growth path, output per effective unit of labour is equal to its steady-state value so labour productivity will grow at the same rate as labour-augmenting technological progress. If a country is below its steady-state level of output per effective labour unit, then its productivity will grow at a faster rate than labour-augmenting technological progress.

A common working and empirical assumption is that countries have the same rate of growth of exogenous technological progress, which implies they have the same steady-state growth rate of per capita income. Heterogeneity is introduced by assuming that countries have the same level of labour-augmenting technological progress but potentially different steady-state output per unit of effective labour (that is, different steady-state ratios of labour productivity to common labour-augmenting technological progress). Without loss of generality we can assume that there is a reference country (denoted by *i=R*) that is growing along its balanced growth path (that is, the reference country's labour productivity grows at the same rate as labour-augmenting technological progress):

$$\ln(x_{Rt}) = \ln(w_{Rt}) - \ln(z_R^*) \quad (3)$$

Substituting (3) into (2) yields the following relationship between the reference and country *i*'s productivity:

$$\begin{aligned}\ln(w_{it} / w_{i,t-1}) &= \ln(w_{Rt} / w_{R,t-1}) - (1-e^{-\beta})\left[\ln(w_{i,t-1}) - \ln(w_{R,t-1}) - \{\ln(z_i^*) - \ln(z_R^*)\}\right] \\ &= \ln(w_{Rt} / w_{R,t-1}) - (1-e^{-\beta})\left[\ln(w_{i,t-1}) - \ln(w_{R,t-1}) - \ln(\xi_i)\right]\end{aligned} \quad (4)$$

where $\xi_i = z_i^* / z_R^*$ is the relative productivity of country *i*.

It follows that country *i*'s productivity growth rate will be higher than the productivity growth rate of the reference country when country *i*'s actual productivity is below its steady-state value, which is equal to the reference country's productivity scaled by country *i*'s relative steady-state productivity level (that is, $\xi_i w_R$).

Country *i* converges absolutely to the reference country if ξ_i is one and converges conditionally to the reference country if ξ_i is less than or greater than one. Empirical studies typically use the United States (US) as the reference country because US productivity has grown persistently over the past 100 years and it tends to be higher than that of other advanced countries. Following this approach, a country's level of conditional convergence is measured as a proportion of US productivity (that is, X per cent of US productivity, hereafter referred to as the steady-state relative productivity). The empirical growth literature has identified a number of factors that are correlated with the measures of conditional convergence which are surveyed by Barro and Sala-i-Martin (2004).

3. DATA

Assuming all parameters are known (β and ξ_i), the framework described by (4) can be used to generate long-term projections of gross domestic product (GDP) growth for countries for which there is historical data and population projections of the working age population. In practice, the model's parameters (β and ξ_i) must be calibrated or estimated from available data and empirical studies. For the reference country, the framework also requires parameters describing the evolution of its trend productivity growth. This section reviews the data underlying the estimates of the model's parameters and projections.[4]

Gross domestic product

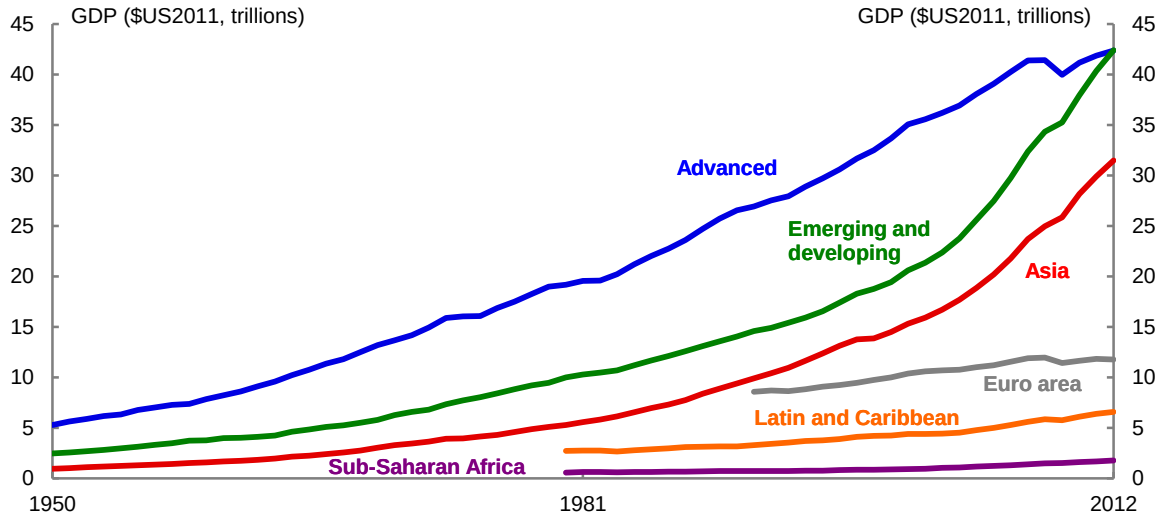
Historical GDP is constructed using three sources, which ensures the broadest possible coverage of economies for the projections: the number of countries covered total 155. The three sources are: the International Monetary Fund's (IMF) World Economic Outlook (WEO) database; the Conference Board's Total Economy Database (TED); and Angus Maddison's historical statistics (1 — 2008AD).

Real GDP growth rates are sourced from the IMF's WEO, which closely match estimates from each country's official statistics bureau. The level of real GDP is based on the 2008 estimate from TED, which uses 2011 US dollar price levels converted at purchasing parity using the Elteto, Koves and Szulc (EKS)

4 See Appendix A for further details of data sources.

methodology.[5] In some cases TED data is not available, so the 2008 level of real GDP from Maddison is used instead. These growth and level data are combined to backcast and forecast the level of real GDP from 1980 to 2017. Where possible these data are backcast further to 1950 using growth rates from the TED and Maddison databases.

Chart 1: Real GDP



Source: Maddison (2010), Conference Board Total Economy Database (2012), IMF World Economic Outlook (April 2012), authors' calculations.

Constructed real GDP levels for selected IMF groups/regions are shown in Chart 1.[6] At the broadest level, world GDP is the sum of advanced and emerging/developing group GDP. Selected GDP subgroups shown in Chart 1 include: the euro area, which is part of the advanced group; Asia, which includes economies in the advanced and emerging/developing groups; and Latin America and the Caribbean, and Sub-Sahara Africa, which belong to the emerging/developing group.

Population

Global demographic estimates and projections are sourced from World Population Prospects (WPP) published by the Population Division of the United Nations (UN). The 2011 Revision, released in May 2011, is the most recent revision of the WPP.[7] This revision projects population from 2011 until 2100, with historical data back to 1950. Projections are based on assumptions regarding future trends in fertility, mortality and international migration. Four fertility scenarios are reported for each country: low; medium; high; and constant. The medium variant (which is also the central case) uses a probabilistic method for projecting total fertility based on empirical fertility trends observed for all countries between 1950 and 2010 (for more information, see United Nations, 2011). Under the low

5 For further details see The Conference Board Total Economy Database™ Methodological Notes – http://www.conference-board.org/retrievefile.cfm?filename=Methodological-Notes_Jan2013.pdf&type=subsite.

6 Appendix B provides a breakdown of economies included in the various defined groupings. Details of IMF region/group definitions can be found on the IMF WEO website, http://www.imf.org/external/pubs/ft/weo/2013/01/weodata/groups.htm.

7 The UN issues a new revision every two years and the next revision is due in the first half of 2013.

variant fertility is projected to remain 0.5 children below the medium variant, while under the high variant fertility is projected to remain 0.5 children above the medium variant. Finally, the constant variant assumes a fertility rate equal to the average fertility rate from 2005 to 2010. Our long-term GDP projections rely on the population projections generated using the medium variant assumption. In particular, we construct country specific productivity using UN projections of working age population, defined as male and females aged between 15 and 64.

Table 1: Working age population (15-64) projections (billions)

	Advanced	Asia	Euro area	Latin and Caribbean	Sub-Saharan Africa
1950	0.39	0.75	0.16	0.09	0.09
1960	0.43	0.86	0.17	0.11	0.12
1970	0.49	1.07	0.18	0.14	0.14
1980	0.55	1.36	0.19	0.19	0.19
1990	0.60	1.74	0.20	0.25	0.25
2000	0.64	2.07	0.21	0.31	0.33
2010	0.68	2.43	0.22	0.37	0.43
2020	0.68	2.65	0.21	0.42	0.56
2030	0.67	2.77	0.21	0.45	0.73
2040	0.66	2.75	0.19	0.46	0.93
2050	0.65	2.70	0.19	0.46	1.14

Source: Authors' calculations and UN (2011).

The working age population projections for selected groups are shown in Table 1. With the exception of Sub-Saharan Africa, which is expected to grow strongly over the next 40 years, regional populations are expected to decline or at least plateau over the projection period. For example, Asia's working age population is expected to peak around 2030 at 2.8 billion and then decline to 2.7 billion by 2050.

Labour productivity

Historical estimates of labour productivity, defined as GDP per worker, are calculated using the historical real GDP levels derived from the IMF, TED and Maddison databases and the UN's historical working age population data. Table 2 shows that the 2010 level of productivity of the advanced group is roughly three times as large as that of combined Asia and ten times as large as that of combined Sub-Saharan Africa.

Table 2: GDP per worker ($US2011, thousands)

	Advanced	Asia	Euro area	Latin and Caribbean	Sub-Saharan Africa	Emerging and developing
1950	12.4	2.4	10.4	6.5	2.1	9.9
1960	17.3	3.2	15.5	9.0	2.6	12.3
1970	25.5	5.1	24.3	12.4	3.4	14.0
1980	33.2	7.6	32.0	14.4	3.7	12.6
1990	39.3	11.4	36.4	13.3	3.8	10.1
2000	49.5	15.7	46.2	15.1	4.2	10.7
2010	56.2	21.1	51.9	17.8	5.8	12.9
2020	68.5	29.9	60.8	22.0	6.9	16.8
2030	80.2	37.1	69.7	24.2	7.3	18.3
2040	94.1	45.4	80.8	27.7	8.1	20.7
2050	110.8	55.1	94.6	32.3	9.3	24.1

Source: Authors' calculations.

4. ESTIMATION

Empirical growth model

It is important to note that the conditional convergence model outlined above provides a framework for studying transitional dynamics over long time horizons. As such it abstracts from short-run cyclical or business cycle fluctuations. This is factored into the projections by assuming that the data have identifiable cyclical (denoted by C superscript) and trend (denoted by T superscript) components:

$$\ln(w_{it}) = \ln(w_{it}^T) + \ln(w_{it}^C) \tag{5}$$

Empirical estimates of cyclical productivity are generated using the following auto-regressive model, where $0<\rho<1$:

$$\ln(w_{it}^C) = \rho \ln(w_{i,t-1}^C) \tag{6}$$

Following the growth literature the US has been chosen as the reference country, which implies the following error correction model for the trend productivity component:

$$\ln(w_{it}^T / w_{i,t-1}^T) = \ln(w_{us,t}^T / w_{us,t-1}^T) - (1-e^{-\beta})\left[\ln(w_{i,t-1}^T) - \ln(w_{us,t-1}^T) - \ln(\xi_i)\right] \tag{7}$$

The final adjustment to the theoretical model is the addition of an acceleration term (that is, lagged productivity growth) to offset the approximation error introduced by linearisation, which implies a more general error correction model:

$$\begin{aligned}\ln(w_{it}^T / w_{i,t-1}^T) = (1-\gamma)\ln(w_{us,t}^T / w_{us,t-1}^T) + \gamma \ln(w_{i,t-1}^T / w_{i,t-2}^T) \\ -(1-e^{-\beta})\left[\ln(w_{i,t-1}^T) - \ln(w_{us,t-1}^T) - \ln(\xi_i)\right]\end{aligned} \tag{8}$$

where $0<\gamma<1$.

Labour-augmenting technological progress is assumed to grow in the long run at a constant rate δ, which implies the following relationship for US trend productivity growth:

$$\ln(w^T_{us,t} / w^T_{us,t-1}) = (1-\gamma)\delta + \gamma \ln(w^T_{us,t-1} / w^T_{us,t-2}) \quad (9)$$

Finally, GDP growth projections are derived using working age population growth rate projections:

$$\ln(y_{it} / y_{i,t-1}) = \ln(w_{it} / w_{i,t-1}) + \ln(n_{it} / n_{i,t-1}) \quad (10)$$

where y_{it} is country *i's* output at time *t* and n_{it} is country *i*'s labour input at time *t*.

Parameter estimation/calibration

Growth rate of labour-augmenting technological progress (δ)

The annual growth rate of US trend productivity (δ) is assumed to be 1.7 per cent. This assumption is based on forecasts of annual US trend productivity growth from 2012 to 2022 published in Congressional Budget Office (2012).

Relative steady-state productivity (ξ_i)

There is a vast empirical literature devoted to the study of conditional convergence. This literature has uncovered a number of institutional factors that are correlated with a country's relative productivity. Using insights from this literature, a set of 66 countries was identified in the broader sample of 155 countries as being at or near their relative US steady-state productivity level.[8] A common empirical observation for this set of countries was that their relative productivity has been roughly constant over the past two decades. The ξ_i for this set of the countries is assumed to be their 2011 level of relative US productivity.

Establishing ξ_i for the remaining 89 countries is somewhat more challenging. Even with the benefit of a large amount of research in this area, it is a challenge to determine (and compile the data for) the factors that should be used in assessing each country's relative steady-state productivity. We circumvent this problem by relying on growth analysis conducted by the World Economic Forum (WEF). In particular, the WEF publishes an annual Global Competiveness Report that analyses the factors underpinning productivity performance, which is summarised by its Global Competitiveness Index (GCI). The GCI provides a score of the competiveness of countries based on over 100 indicators that, theoretically and empirically, have been shown to be important in determining a country's productivity (see, Sala-i-Martin and Artadi, 2004, and WEF, 2012, for more details).

We use the WEF's GCI scores and the relative productivity estimates of the previously identified 66 near steady-state countries to estimate the relationship between relative steady-state productivity ξ_i and the GCI. Non-parametric techniques (kernel regressions) are employed to avoid having to make strong structural or parametric assumptions about the relationship between the GCI and ξ_i. The relative steady-state productivities of the remaining 89 countries are then predicted using each country's GCI

8 See Appendix B for the list of countries determined to be at their steady-state productivity ratio.

score and the estimated relationship. The kernel regression used to estimate the relationship between ξ and GCI is:

$$\bar{\xi}(GCI) = \frac{\sum_{j=1}^{m} K(\psi_j)\xi_j}{\sum_{j=1}^{m} K(\psi_j)} \tag{11}$$

where *m* is the number of near steady-state countries, $\psi_j = \frac{GCI_j - GCI}{h}$, ξ_j is the ratio of each country's productivity to the US, *h* is the estimation bandwidth and $K(\psi_j) = \frac{1}{\sqrt{2\pi}} exp\left[\frac{-1}{2}\psi_j^2\right]$ is a Gaussian kernel. The choice of the bandwidth can affect the estimates in a non-trivial manner. Larger values of *h* will lower the variance of the kernel estimates but potentially increase the bias (see Pagan and Ullah, 1999, for a more extensive discussion). We minimised our choice of *h* subject to the constraint that the relationship between ξ_I and GCI is monotonically increasing.

Chart 2 shows the estimated relationship between the relative productivities of the 66 countries that are at or near steady state and their GCI. This regression line implies there are two critical GCI scores: GCIs below 3.8 are associated with low relative productivity and modest gains in productivity for an increase in GCI; GCIs above 4.8 are associated with relatively high productivity and modest gains in productivity for an increase in GCI; and for GCI's between 3.8 and 4.8 small increases in GCI imply significantly higher relative productivity gains.

The WEF does not publish GCI estimates for 23 economies of the 155 of the countries under study. We circumvent this problem by using the Worldwide Governance Indicators (WGI) published via World Bank (2012) to derive an equivalent GCI value. The WGI is chosen as there is some overlap in the sets of institutional factors covered by each index. Specifically, the six dimensions of the WGI include: voice and accountability; political stability and absence of violence/terrorism; government effectiveness; regulatory quality; and rule of law and control of corruption. Consistent with this overlap, we find a fairly close correlation between the GCI and WGI. On this basis, a WGI to GCI mapping equation is estimated for the 132 available economies using a linear regression of GCI on WGI and a constant:

$$GCI_i = \alpha_0 + \alpha_1 WGI_i \tag{12}$$

The estimated relationship is then used to map WGI to GCI for the 23 economies that do not have GCI scores. The results of the regression are presented in Appendix C.

Chart 2: Estimated relationship between relative steady-state productivity and the WEF's global competitiveness index

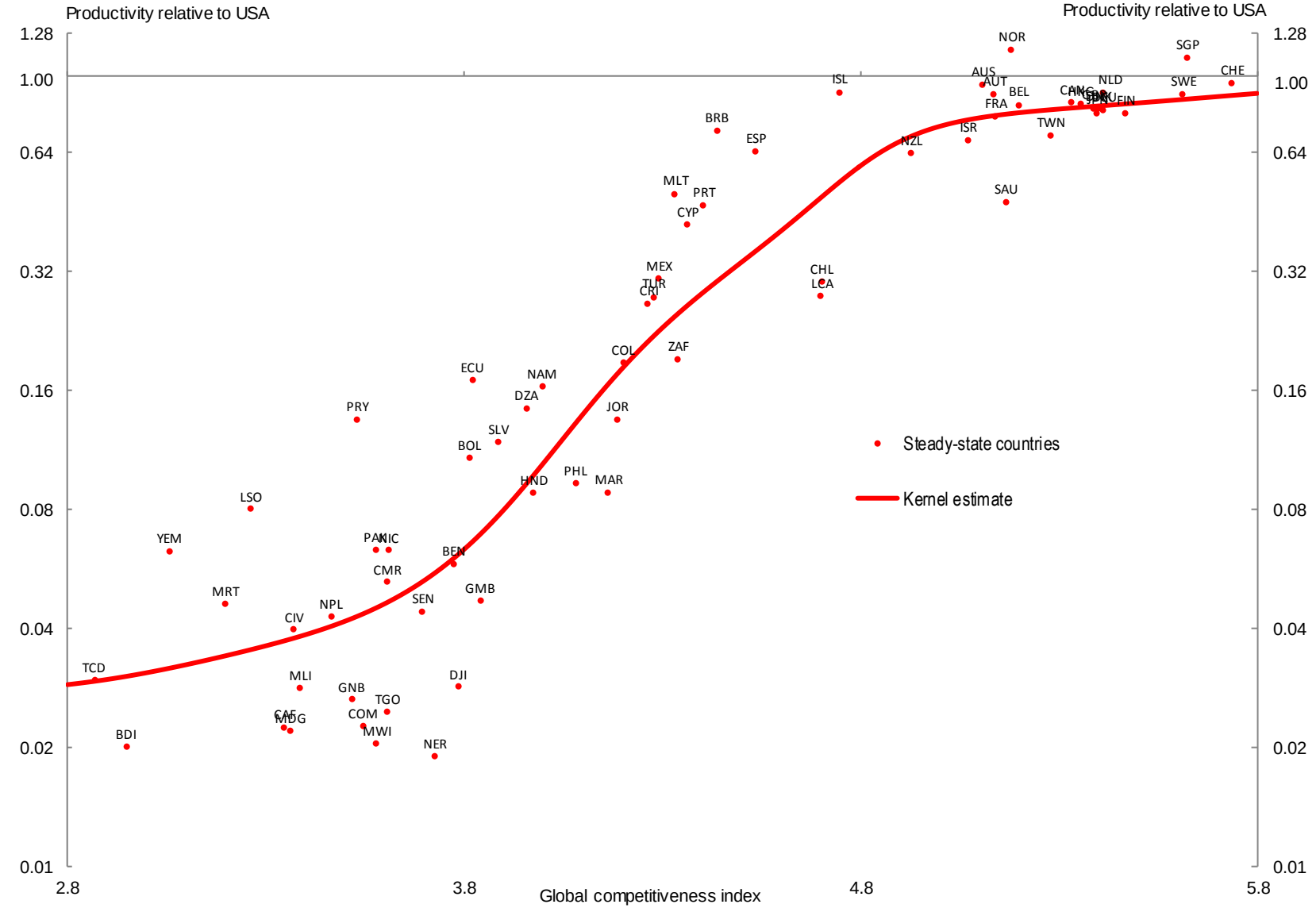


Chart 3: Current versus steady-state relative labour productivity

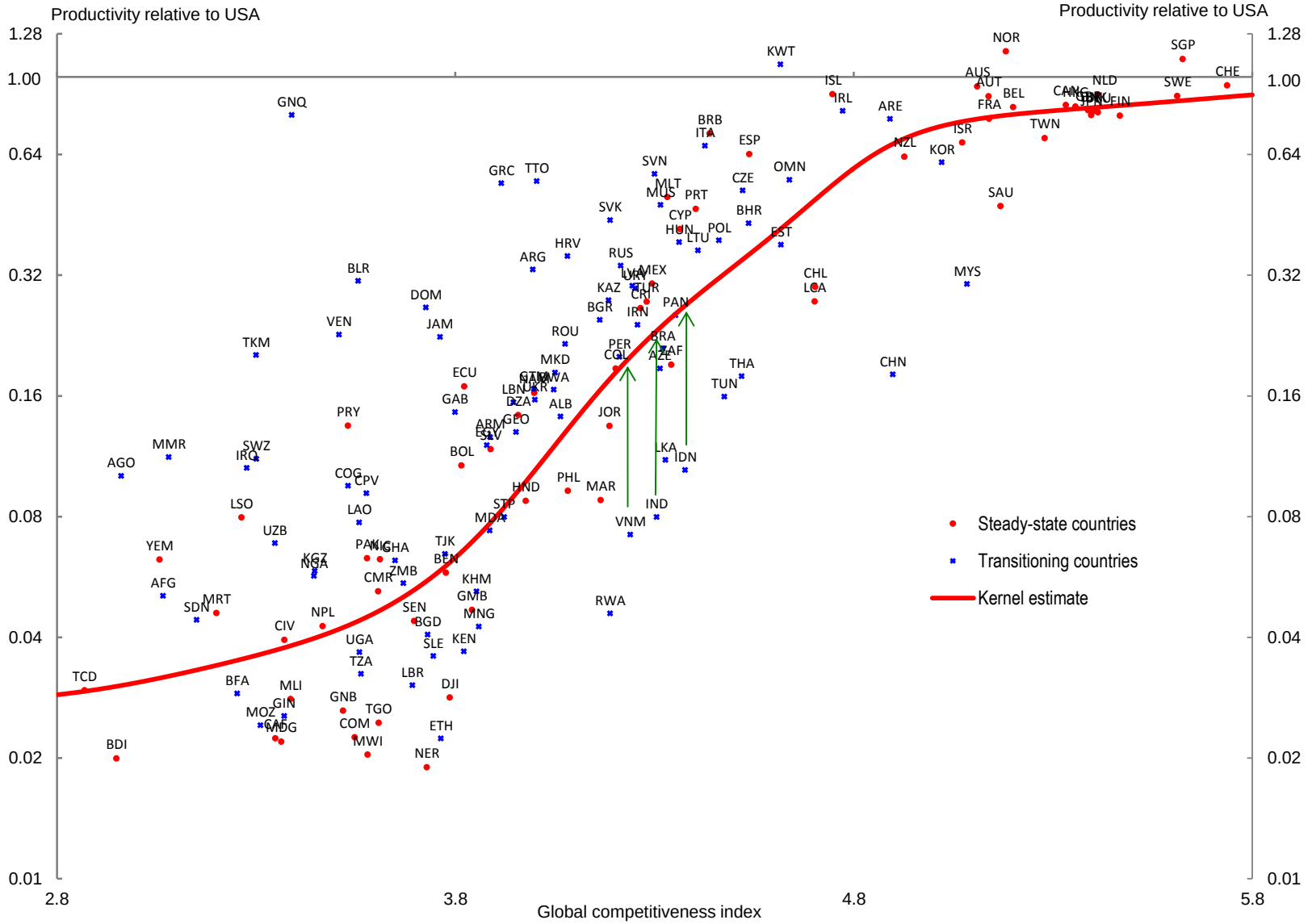


Chart 3 plots the level of 2011 relative productivity against the GCI for all countries under study, along with the estimated relationship between steady-state relative productivity and GCI. A number of countries have current levels of relative productivity that lie well below their expected steady-state level. For example, India, Indonesia and Vietnam (highlighted by green arrows) currently have productivity levels around 10 per cent of the US level and are expected to have a steady-state level of around 20 per cent of US productivity level. There are several countries that currently lie well-above their expected steady-state relative productivity. Most of these countries are located in the Middle East and North African region (see Appendix B for complete list), with rich natural resources such as oil. Our analysis suggests that growth convergence factors summarised by the GCI will be a constraint on their long-term growth prospects.

Speed of convergence (β)

The speed of convergence, β, depends on long-run technology and preference parameters, which are assumed to be common to all countries. Under this assumption the speed of convergence can be identified from panel regressions across all countries where each country's transitional dynamics are captured by equation (2). Empirical studies that follow this approach, such as Barro (1991), Barro and Sala-i-Martin (1992 and 2004), Barro, Sala-i-Martin, Blanchard, and Hall (1992) and Mankiw, Romer and Weil (1992), find that countries converge on average at an annual rate of around 2 per cent. Consistent with these studies, we assume a speed of convergence of 2 per cent for all economies.

In the case of China, whose current level of relative US productivity is around 20 per cent, a convergence rate of 2 per cent implies it will reach a relative productivity level of just over 50 per cent of the US by 2050, which is still well below its expected steady-state value of around 70 per cent.

Growth acceleration (γ)

The linearised model summarised in (2) assumes a fixed speed of convergence. Barro and Sala-i-Martin (1992 and 2004) show that the exact speed of convergence is a decreasing function of the distance from the balanced growth path. This is captured in the empirical model by the acceleration term (γ) which is calibrated to be 0.5.

Cyclical productivity (ρ)

Historical labour productivity data are de-trended using the Hodrick-Prescott (HP) filter, with a λ of 6.25 which is consistent with the recommendations of Baxter and King (1999) and Ravn and Uhlig (2002). The cyclical components generated by this filter imply ρ is equal to 0.65.

5. RESULTS

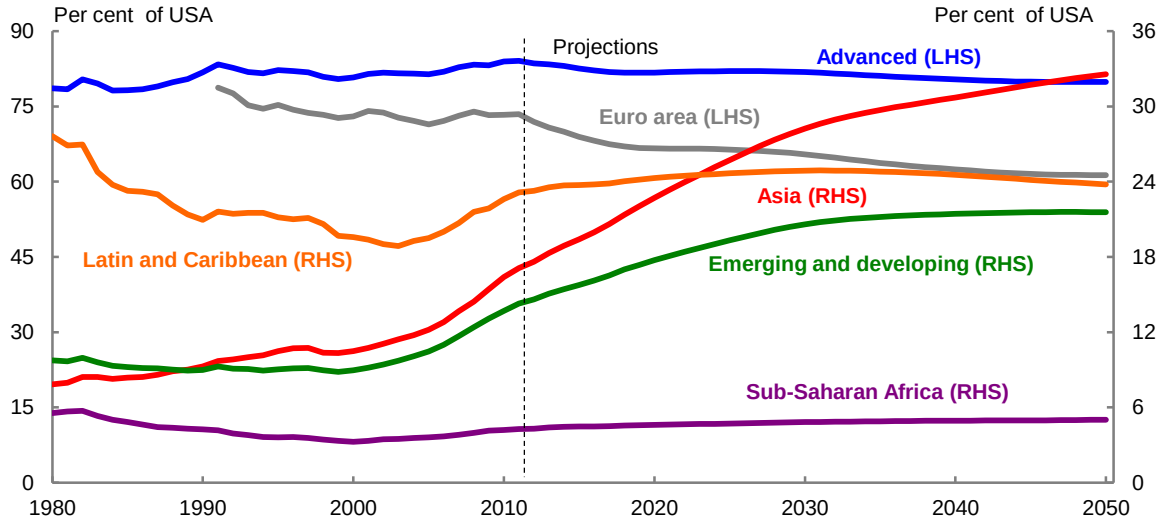
This section summarises key results produced by the long-term GDP projection framework.

Relative productivity

Relative productivity is projected to remain stable for advanced, Sub-Saharan Africa, and Latin America and Caribbean economies throughout the projection period (see Chart 4), while the relative

productivity level of the Asian region is expected to more than double from around 15 per cent in 2012 to around 32 per cent by 2050. This is also the source of the rising relative productivity level of the broader emerging and developing region.

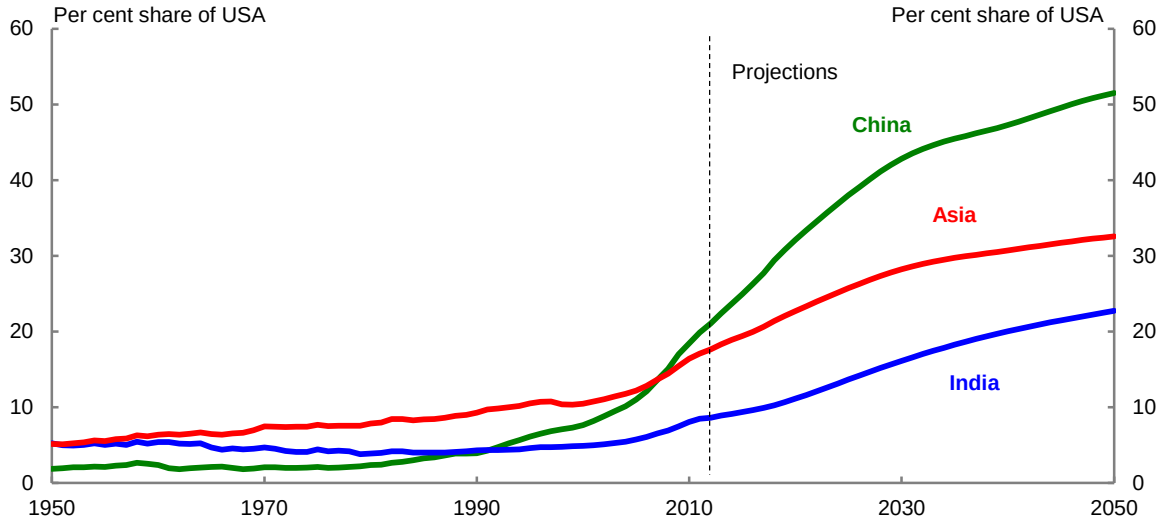
Chart 4: Relative productivity by region



Source: Authors' calculations.

Turning to countries within the Asia region, we see that China's relative productivity level is expected to more than double from its current level of around 20 per cent to a little over 50 per cent by 2050 (see Chart 5). India's relative productivity level is also expected to double over this period, albeit from a lower base of around 10 per cent.

Chart 5: Relative productivity — Asia

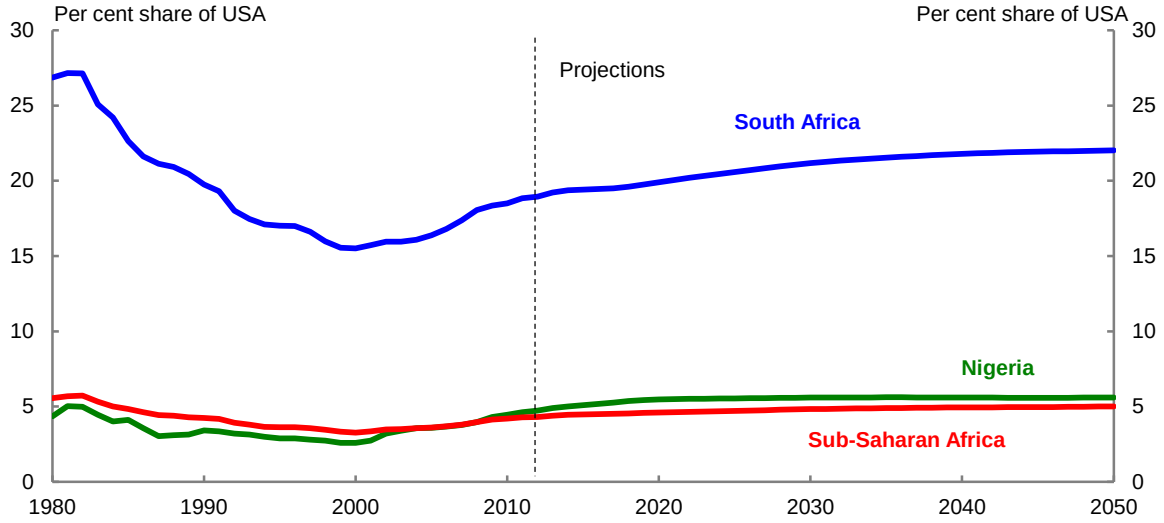


Source: Authors' calculations.

Many of the countries in the Sub-Saharan Africa region are scattered above and below the lower-left segment the relative productivity-GCI curve (see Chart 3). Therefore, we expect the relative productivity level of the Sub-Saharan Africa region to rise slightly over the projection period from its current level of around 4 per cent to 5 per cent by 2050 (see Chart 6). Underlying this are modest

improvements in the relative productivity of large countries in the region, such as South Africa and Nigeria.

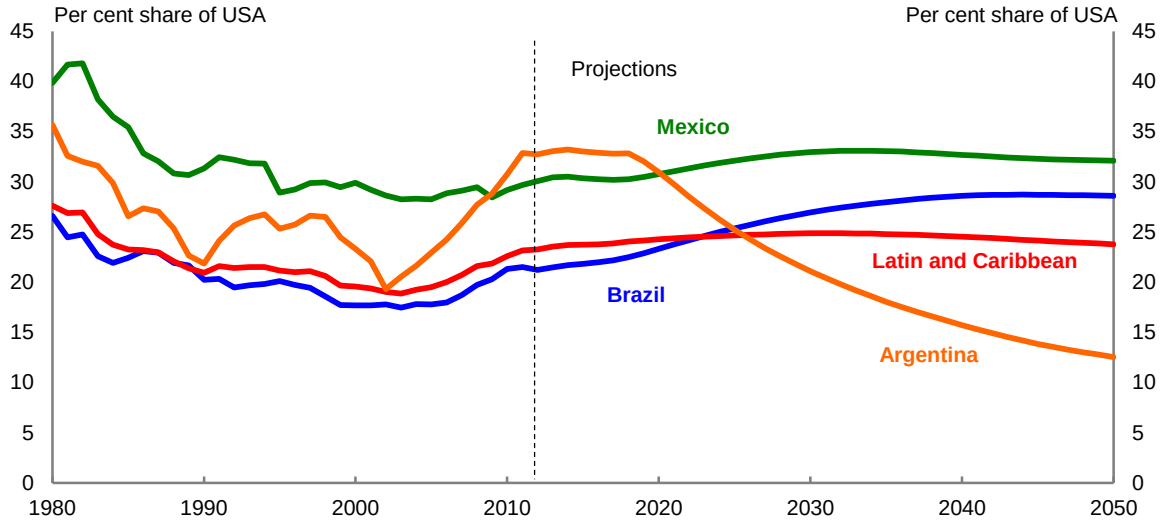
Chart 6: Relative productivity — Sub-Saharan



Source: Authors' calculations.

At around 25 per cent of the US level, the current relative productivity level of the Latin America and Caribbean region is somewhat higher than that of the Sub-Saharan Africa region. Our analysis suggests there will be little improvement in the Latin America and Caribbean region's relative productivity level over the next 40 years, as projected improvements in countries such as Brazil are expected to be offset by declines in other countries, such as Argentina (see Chart 7).

Chart 7: Relative productivity — Latin America and Caribbean



Source: Authors' calculations.

Regional transition paths

Table 3 highlights that emerging and developing economies have been the major driver of global economic growth over the last decade. This was particularly true for the years surrounding the global financial crisis, over which the advanced economies displayed, by their own historical levels, relatively weak growth. This pattern is expected to continue over the next two decades, with the emerging and

developing region expected to grow at twice the average annual rate of the advanced region (largely due to strong growth in Asia). Sub-Saharan Africa's GDP is also expected to grow strongly over the projection period due to strong population growth.

World output growth is expected to slow from an average annual rate of around 4 per cent from 2010 to 2020 to an annual average growth rate of around 2 per cent from 2040 to 2050. Again, this largely reflects developments in Asia, with average annual Asian GDP growth expected to fall from 6.1 per cent from 2010 to 2020 to 2.3 per cent from 2040 to 2050.

Table 3: GDP growth projections by region (average annual growth)

	World	Advanced economies	Emerging and developing economies	Euro area	Asia	Latin America and Caribbean	Sub-Saharan Africa
1950-1960	4.7	4.6	4.9		5.9		
1960-1970	5.0	5.2	4.6		6.9		
1970-1980	3.8	3.4	4.8		4.8		
1980-1990	3.3	3.3	3.4		5.9	1.5	2.4
1990-2000	3.2	2.8	3.9		5.0	3.3	2.3
2000-2010	3.6	1.6	6.3	1.2	6.3	3.3	5.7
2010-2020	4.0	2.1	5.7	1.1	6.1	3.7	5.3
2020-2030	2.9	1.6	3.7	1.2	4.0	2.3	4.0
2030-2040	2.3	1.6	2.7	1.1	2.7	1.9	3.9
2040-2050	2.1	1.7	2.2	1.4	2.3	1.6	3.6

Source: Authors' calculations.

Unsurprisingly, the two countries driving the strong Asian region growth are China and India (see Table 4). The relative productivity level of these countries is expected to rise by roughly the same amount (that is, they are expected to double) which implies their annual GDP growth rates will receive the same boost from growth convergence factors. In the case of India, the relative productivity improvement is coming off a significantly lower base, so any further improvement in its growth convergence criteria that pushes its GCI closer to China's would imply significantly stronger growth over the projection period.

Sub-Saharan Africa's combined GDP is expected to grow at an annual rate of above 3 per cent over the projection period. Given the modest improvement expected in the region's relative productivity, this in large part reflects strong population growth, with the region's population expected to double over the next 40 years (see Table 5).

The growth prospects of the Latin America and Caribbean region are more modest than Sub-Saharan Africa's. This reflects little expected improvement in the former's relative productivity and its relative weak population growth (see Table 6).

Table 4: GDP projections — Asia (average annual growth)

	Asia	China	India
1950-1960	5.9	6.1	3.9
1960-1970	6.9	3.7	3.7
1970-1980	4.8	5.5	2.8
1980-1990	5.9	9.3	5.6
1990-2000	5.0	10.4	5.6
2000-2010	6.3	10.5	7.4
2010-2020	6.1	8.0	6.5
2020-2030	4.0	4.3	6.1
2030-2040	2.7	2.4	4.5
2040-2050	2.3	2.0	3.3

Source: Authors' calculations.

Table 5: GDP projections — Sub-Saharan Africa (average annual growth)

	Sub-Saharan Africa	Nigeria	South Africa
1950-1960		3.6	4.4
1960-1970		6.0	5.7
1970-1980		5.0	3.4
1980-1990	2.4	2.4	1.5
1990-2000	2.3	1.9	1.8
2000-2010	5.7	8.9	3.5
2010-2020	5.3	6.6	3.1
2020-2030	4.0	3.9	2.3
2030-2040	3.9	3.8	2.1
2040-2050	3.6	3.7	1.9

Source: Authors' calculations.

Table 6: GDP projections — Latin America and the Caribbean (average annual growth)

	Latin America and Caribbean	Brazil	Mexico
1950-1960		6.5	6.1
1960-1970		5.7	6.5
1970-1980		8.2	6.7
1980-1990	1.5	1.5	1.9
1990-2000	3.3	2.5	3.5
2000-2010	3.3	3.6	1.6
2010-2020	3.7	3.6	3.5
2020-2030	2.3	3.2	2.7
2030-2040	1.9	2.4	2.0
2040-2050	1.6	1.6	1.6

Source: Authors' calculations.

Table 7 reports the long-term GDP projections of other agencies/institutions. The frameworks used by these institutions are similar to the approach presented in this paper, with GDP projections based on

assumptions about the growth rates of the labour force and labour productivity. Treasury's outlook for world output growth is broadly consistent with the expectations of these other forecasters over the current decade (that is, from 2010 to 2020). In contrast, Treasury's long-term outlook of average annual world output growth is in the range of 2 per cent which is somewhat weaker than Goldman Sachs' expectation of average annual growth of above 3 per cent.

Table 7: GDP projection by other agencies/institutions

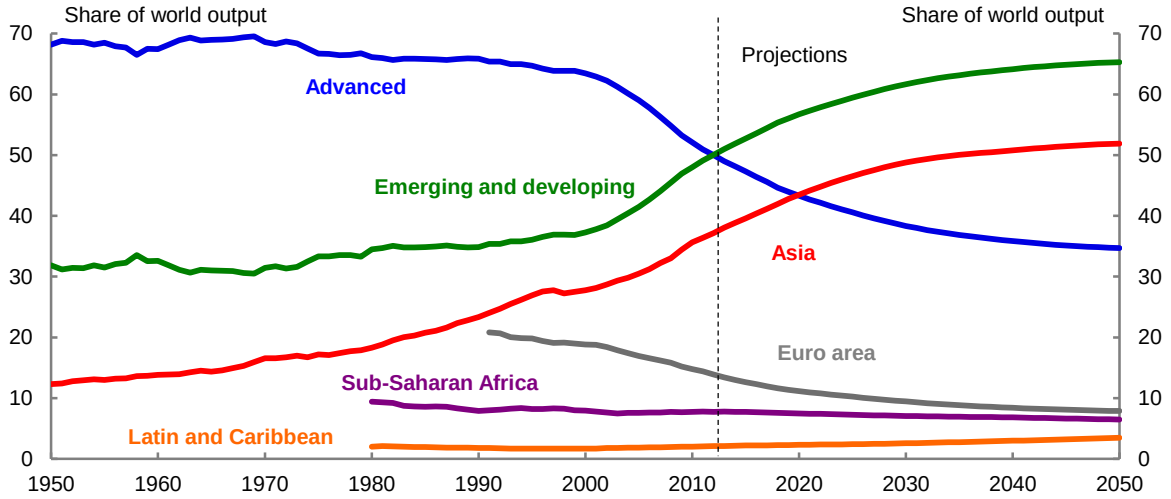
Institution	Publication date	Time Period	World	China	India
Conference Board (a)	2011	2012-2016	3.4	6.8	6.2
		2017-2025	2.7	3.5	4.5
World Bank (b)	2009	2010-2015		8.4	
		2016-2020		7	
Garnaut (c)	2008	2005-2015	4.6	9	7.5
		2015-2025	4.4	6.8	7.5
Carnegie Endowment (d)	2010	2009-2050		5.6	5.9
Asian Development Bank (e)	2010	2011-2030		5.5	4.5
Goldman Sachs (f)	2011	2010-2019	4.3	7.5	6.9
		2020-2029	3.9	5.4	6
		2030-2039	3.5	3.5	5.7
		2040-2050	3.3	2.9	5.1
HSBC (g)	2012	2010-2020		6.7	5.7
		2020-2030		5.5	5.6
		2030-2040		4.4	5.5
		2040-2050		4.1	5.2
PWC (h)	2011	2009-2050		5.9	8.1
BBVA (i)	2012	2011-2021	4.3	8.4	7.8

Source: (a) Chen, et al. (2012), (b) Kuijs (2009), (c) Garnaut (2011), (d) Dadush and Stancil (2010), (e) Asian Development Bank (2011), (f) Wilson, et al. (2011), (g) Ward (2012), (h) PWC (2011), (i) BBVA(2012) and authors' calculations.

Regional economic importance

Our analysis suggests that the economy of the emerging and developing region is currently larger than the economy of the advanced region (see Chart 8). This reflects the rapidly shifting weight of global economic activity to the fast-growing economies of Asia. We project that Asia will become the world's largest economic region by 2020. Underlying this is the expectation that the combined economies of China and India will be larger than the economy of the advanced region by the middle of the 2030s. Chart 8 reveals that the rising global share of Asia will be offset by declining shares for both the advanced and Latin America and Caribbean regional economies.

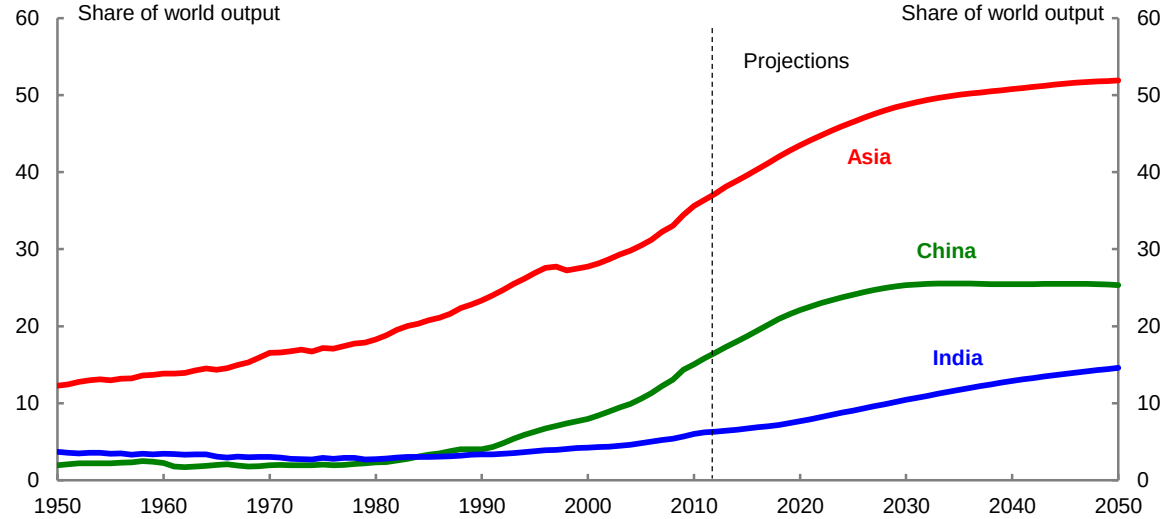
Chart 8: Regional economic shares



Source: Authors' calculations.

The re-emergence of China and India is particularly extraordinary due to the pace at which is it is occurring. According to Maddison (2010), during the Industrial Revolution, it took about 50 years for the United Kingdom to almost double its share of world output. Chart 9 shows that China doubled its share of world output in just over a decade from when it began its market oriented reforms in 1978. Moreover, in the thirty years since reforms began, China's share of world output has increased almost eight-fold. Similarly, India began its wave of reforms in the early 1990s and doubled its share of world GDP in under two decades.

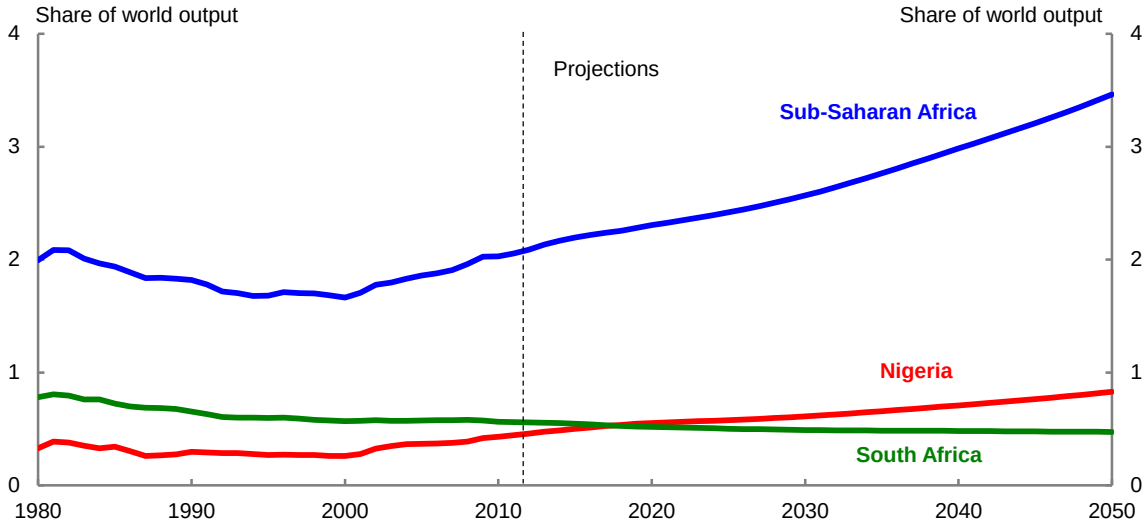
Chart 9: Regional economic shares — Asia



Source: Authors' calculations.

The Sub-Saharan Africa region's share of world output is currently around 2 per cent. We expect this share to rise to 3.5 per cent by 2050 (see Chart 10). Nigeria and South Africa are expected to be the major economies of the Sub-Saharan Africa region over this period, with Nigeria's importance rising steadily in the region from 0.5 per cent of world GDP today to just under 1 per cent by 2050.

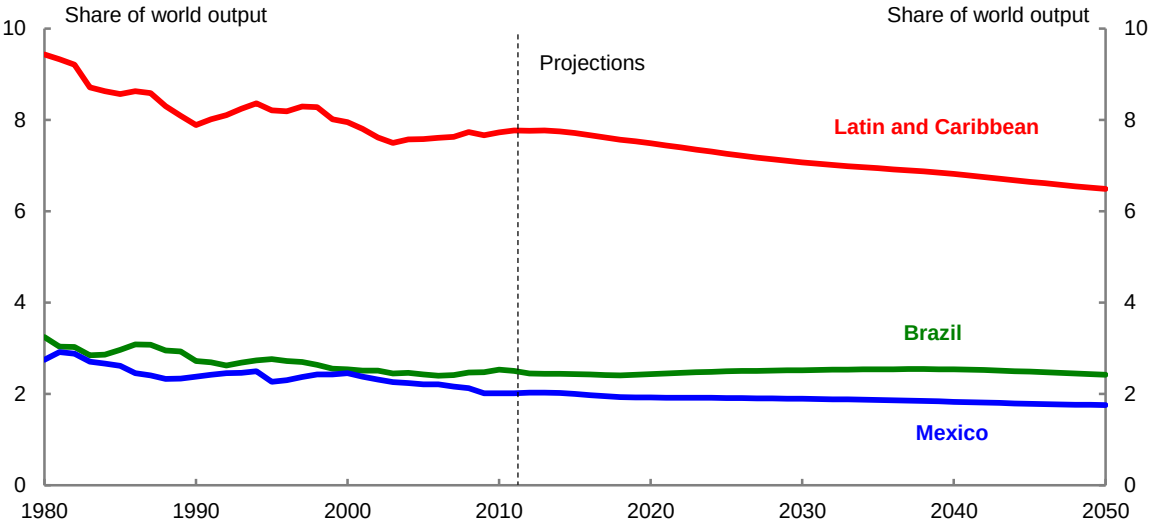
Chart 10: Regional economic shares — Sub-Saharan Africa



Source: Authors' calculations.

The Latin America and Caribbean region is expected to grow at a slower pace than world output, which implies its share of world output will decline from around 8 per cent in 2012 to 6.5 per cent in 2050. Chart 11 shows that the region's projected global share path is consistent with its trend over the past 30 years.

Chart 11: Regional economic shares — Latin America and Caribbean



Source: Authors' calculations.

Table 8: Ranking by size of economy

Ranking	1980	2010	2030	2050
1	USA	USA	China	China
2	Japan	China	USA	USA
3	Germany	Japan	India	India
4	France	India	Japan	Indonesia
5	Italy	Germany	Germany	Japan
6	Great Britain	Great Britain	Brazil	Brazil
7	Brazil	Russia	Indonesia	Great Britain
8	Mexico	France	Great Britain	Germany
9	India	Brazil	France	France
10	Canada	Italy	Mexico	Mexico
11	Spain	Mexico	Russia	Saudi Arabia
12	China	Korea	Korea	Canada
13	Australia	Spain	Canada	Korea
14	Netherlands	Canada	Spain	Australia
15	Poland	Indonesia	Italy	Russia
16	Saudi Arabia	Australia	Turkey	Malaysia
17	Argentina	Iran	Australia	Spain
18	Iran	Turkey	Saudi Arabia	Turkey
19	Indonesia	Taiwan	Iran	Thailand
20	Turkey	Poland	Thailand	Nigeria

Source: Authors' calculations.

Table 8 reports the ranking of individual economies according to their share of world output. China is expected to be the world's largest economy by 2030 followed by the US and India. Indonesia is on track to become the fourth largest economy by 2050, which implies that four of the five largest economies in the world will be in Asia.

6. CONCLUSION

For a small open economy, such as Australia, international trade is an important determinant of economic growth, so long-term growth projections typically rely on a considered view of the long-term outlook of its trading partners. This paper develops a framework for projecting the GDP growth of Australia's trading partners from 2012 to 2050 that is suitable for that task. The projection framework draws heavily on the existing conditional growth literature, including long-standing estimates of key convergence parameters. It adds to the large amount of research in this area by providing estimates of the level of long-run relative productivity for 155 countries. We use a novel non-parametric approach that combines the World Economic Forum ordinal measure of long-run relative productivity (that is, the Global Competitiveness Index) and actual observed productivity to produce a cardinal measure of long-run relative productivity.

Our analysis suggests that the economy of the emerging and developing region is currently larger than the economy of the advanced region. This reflects the rapidly shifting weight of global economic activity

to the fast-growing economies of Asia. We project that Asia will become the world's largest economic region by 2020. Underlying this is the expectation that the combined economies of China and India will become larger than the combined advanced economies by the middle of the 2030s. Furthermore, our analysis predicts the rising global share of Asia will be offset by declining shares for both the advanced and Latin America and Caribbean regional economies. Finally, we expect that four of the five largest economies in the world will be in Asia by 2050 (China, India, Indonesia and Japan).

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APPENDIX A: DATA SOURCES

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APPENDIX B: COUNTRY LISTS[9]

Country Name	Country Code	Near steady state	Region
Albania	ALB		EMDEV
Algeria	DZA	*	EMDEV
Angola	AGO		EMDEV
Argentina	ARG		EMDEV
Armenia	ARM		EMDEV
Australia	AUS	*	Advanced
Austria	AUT	*	Advanced
Azerbaijan	AZE		EMDEV
Bahrain	BHR		EMDEV
Bangladesh	BGD		EMDEV
Barbados	BRB	*	EMDEV
Belarus	BLR		EMDEV
Belgium	BEL	*	Advanced
Benin	BEN	*	EMDEV
Bolivia	BOL	*	EMDEV
Botswana	BWA		EMDEV
Brazil	BRA		EMDEV
Bulgaria	BGR		EMDEV
Burkina Faso	BFA		EMDEV
Burundi	BDI	*	EMDEV
Cambodia	KHM		EMDEV
Cameroon	CMR	*	EMDEV
Canada	CAN	*	Advanced
Cape Verde	CPV		EMDEV
Central African Republic	CAF	*	EMDEV
Chad	TCD	*	EMDEV
Chile	CHL		EMDEV
China	CHN		EMDEV
Colombia	COL	*	EMDEV
Comoros	COM	*	EMDEV
Costa Rica	CRI	*	EMDEV
Côte d'Ivoire	CIV	*	EMDEV
Croatia	HRV		EMDEV
Czech Republic	CZE		Advanced
Democratic Republic of Congo	COD	*	EMDEV
Denmark	DNK	*	Advanced
Djibouti	DJI	*	EMDEV
Dominican Republic	DOM		EMDEV

9 EMDEV = emerging and developing economies. ** Oil rich economies that are transitioning to a lower long-run relative steady-state level.

Country Name	Country Code	Near steady state	Region
Ecuador	ECU	*	EMDEV
Egypt	EGY		EMDEV
El Salvador	SLV	*	EMDEV
Equatorial Guinea	GNQ		EMDEV
Islamic Republic of Afghanistan	AFG		EMDEV
Republic of Congo	COG		EMDEV
Ecuador	ECU		EMDEV
Egypt	EGY		EMDEV
El Salvador	SLV	*	EMDEV
Equatorial Guinea	GNQ	*	EMDEV
Islamic Republic of Afghanistan	AFG		EMDEV
Republic of Congo	COG	*	EMDEV
Estonia	EST		Advanced
Ethiopia	ETH		EMDEV
Finland	FIN	*	Advanced
France	FRA	*	Advanced
Gabon	GAB		EMDEV
The Gambia	GMB	*	EMDEV
Georgia	GEO		EMDEV
Germany	DEU	*	Advanced
Ghana	GHA		EMDEV
Greece	GRC		Advanced
Guatemala	GTM		EMDEV
Guinea	GIN		EMDEV
Guinea-Bissau	GNB	*	EMDEV
Honduras	HND	*	EMDEV
Hong Kong SAR	HKG	*	Advanced
Hungary	HUN		EMDEV
Iceland	ISL	*	Advanced
India	IND		EMDEV
Indonesia	IDN		EMDEV
Islamic Republic of Iran	IRN	**	EMDEV
Iraq	IRQ	**	EMDEV
Ireland	IRL		Advanced
Israel	ISR	*	Advanced
Italy	ITA		Advanced
Jamaica	JAM		EMDEV
Japan	JPN	*	Advanced
Jordan	JOR	*	EMDEV
Kazakhstan	KAZ		EMDEV
Kenya	KEN		EMDEV
Korea	KOR		Advanced
Kuwait	KWT	**	EMDEV
Kyrgyz Republic	KGZ		EMDEV
Lao People's Democratic Republic	LAO		EMDEV

Country Name	Country Code	Near steady state	Region
Latvia	LVA		EMDEV
Lebanon	LBN	**	EMDEV
Lesotho	LSO	*	EMDEV
Liberia	LBR		EMDEV
Lithuania	LTU		EMDEV
Luxembourg	LUX	**	Advanced
Former Yugoslav Republic of Macedonia	MKD		EMDEV
Madagascar	MDG	*	EMDEV
Malawi	MWI	*	EMDEV
Malaysia	MYS		EMDEV
Mali	MLI	*	EMDEV
Malta	MLT	*	Advanced
Mauritania	MRT	*	EMDEV
Mauritius	MUS		EMDEV
Mexico	MEX	*	EMDEV
Moldova	MDA		EMDEV
Mongolia	MNG		EMDEV
Morocco	MAR	*	EMDEV
Mozambique	MOZ		EMDEV
Myanmar	MMR		EMDEV
Namibia	NAM	*	EMDEV
Nepal	NPL	*	EMDEV
Netherlands	NLD	*	Advanced
New Zealand	NZL	*	Advanced
Nicaragua	NIC	*	EMDEV
Niger	NER	*	EMDEV
Nigeria	NGA		EMDEV
Norway	NOR	*	Advanced
Oman	OMN	**	EMDEV
Pakistan	PAK	*	EMDEV
Panama	PAN		EMDEV
Paraguay	PRY	*	EMDEV
Peru	PER		EMDEV
Philippines	PHL	*	EMDEV
Poland	POL		EMDEV
Portugal	PRT	*	Advanced
Qatar	QAT	**	EMDEV
Romania	ROU		EMDEV
Russia	RUS		EMDEV
Rwanda	RWA		EMDEV
São Tomé and Príncipe	STP		EMDEV
Saudi Arabia	SAU	*	EMDEV
Senegal	SEN	*	EMDEV
Sierra Leone	SLE		EMDEV
Singapore	SGP	*	Advanced

Country Name	Country Code	Near steady state	Region
Slovak Republic	SVK		Advanced
Slovenia	SVN		Advanced
South Africa	ZAF	*	EMDEV
Spain	ESP	*	EMDEV
Sri Lanka	LKA		Advanced
St. Lucia	LCA	**	Advanced
Sudan	SDN		Advanced
Swaziland	SWZ		EMDEV
Sweden	SWE	*	Advanced
Switzerland	CHE	*	Advanced
Taiwan Province of China	TWN	*	Advanced
Tajikistan	TJK		EMDEV
Tanzania	TZA		EMDEV
Thailand	THA		EMDEV
Togo	TGO	*	EMDEV
Trinidad and Tobago	TTO	**	EMDEV
Tunisia	TUN		EMDEV
Turkey	TUR	*	EMDEV
Turkmenistan	TKM		EMDEV
Uganda	UGA		EMDEV
Ukraine	UKR		EMDEV
United Arab Emirates	ARE	**	EMDEV
United Kingdom	GBR	*	Advanced
United States	USA	*	Advanced
Uruguay	URY		EMDEV
Uzbekistan	UZB		EMDEV
Venezuela	VEN	**	EMDEV
Vietnam	VNM		EMDEV
Republic of Yemen	YEM	*	EMDEV
Zambia	ZMB		EMDEV
Zimbabwe	ZWE		EMDEV

APPENDIX C: WGI TO GCI MAPPING

Table 9: Estimated WGI to GCI mapping

Variable	*Parameter estimate (standard error)*
α_0	4.15
	(0.03)
α_1	0.61
	(0.04)
N	122
R^2	0.67

Using these parameter estimates the following GCI scores are obtained for the 23 countries without official GCI scores:

Table 10: Estimated GCI values for missing countries

Belarus	3.56	Liberia	3.69
Comoros	3.55	Myanmar	3.08
Central African Republic	3.35	Niger	3.73
Democratic Republic of Congo	3.14	Republic of Congo	3.53
Djibouti	3.79	São Tomé and Príncipe	3.92
Equatorial Guinea	3.39	Sierra Leone	3.75
Gabon	3.8	St. Lucia	4.7
Guinea	3.37	Sudan	3.15
Guinea-Bissau	3.52	Togo	3.61
Iraq	3.28	Turkmenistan	3.3
Islamic Republic of Afghanistan	3.07	Uzbekistan	3.35
Lao People's Democratic Republic	3.56		