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Australia: a land of missed opportunities?

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Abstract:

Comprehensive Investment (CI) may provide an indicator of future changes in a country's per capita consumption. We explore the utility of the CI indicator for Australia by constructing CI data since 1861 and by estimating their relationship with changes in future consumption over periods of 50 years ahead. The CI measures include changes in natural, produced and human capital, and make allowance for exogenous technological progress. The results are used to consider how Australia's natural capital exploitation influenced the consumption of future generations. Further, we gauge if low CI relative to other leading OECD countries resulted in lower consumption levels in Australia over time than feasible, had it saved more.

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1. Introduction: Comprehensive Investment as an indicator of sustainable development

The idea of using a nation's Comprehensive Investment, CI, (also referred to as Genuine Savings, Inclusive Investment and Adjusted Net Savings) as a forward-looking indicator of "weak" sustainability is well-established (Hamilton and Clemens, 1999, Pezzey, 2004, Arrow et al, 2012). Weak sustainability assumes that all forms of capital – produced, natural, human and social capital - are perfectly substitutable, and can be measured and aggregated using a given numeraire. Pearce and Atkinson (1993) were the first to suggest that the change over

time in a country's total capital stocks (the sum of produced, human, natural and social capital) indicates the sustainability of its consumption into the future. Sustainable development, as defined by Arrow et al (2012), postulates an economic path where intergenerational well-being, defined as the present value of discounted utility from consumption, does not decline over time. CI estimates have been reported for virtually all of the world's economies, typically using World Bank datasets (World Bank, 2006, UNEP, 2012) for years after 1970, although several longer time series of CI for individual countries are also available (Lindmark and Acar, 2013, Greasley et al, 2014, Hanley et al 2015).

For natural resource abundant economies, Hartwick (1977) developed 'a rule of thumb' for constant consumption over time, which required the re-investment of rents from natural resource extraction in capital stocks along a competitive path in a Cobb-Douglas economy. Hamilton, Ruta and Tajibaeva (2006), hereafter HRT, generalized this "Hartwick rule" and illustrated the possibility of unbounded and rising consumption if a CI rate of at least 5% of GDP was maintained over time. Since HRT's generalization of the Hartwick rule provides a policy yardstick for raising consumption over generations, it offers a relevant and possibly appealing prescription for resource-rich developed countries such as Australia.

This paper draws upon the theory of weak sustainability to investigate central issues in Australian political economy surrounding the utilization of natural resource rents and its comprehensive investment over time. Low rates of national savings have been mooted as characteristic of Australia's economy (McLean, 2013, Greasley, 2015). The establishment of nation-building wealth funds in 2008 to support investment in infrastructure, health and education illustrates the concern that consumption growth has rested on resource depletion and may be unsustainable (Australian Government Future Fund, 2014). In this paper, we extend the standard macro measure of saving to include accumulation of *all* forms of capital: produced, human, natural and social. Our purpose lies in gauging how Australia utilized its

natural resource rents over time, and in particular whether higher consumption growth might have been sustained by Australia had it matched the CI of three “comparator” countries, namely Britain, Germany, and the USA. HRT, show, with post-1970 data, that consumption rather than investment of resource rents is common among resource-rich countries, to the detriment of future generations, but they do not consider Australia. Randall (2008), also using post-1970 World Bank data, describes Australia as “muddling along”, with adjusted net savings of around 5% of GDP, but he questions if its genuine savings are positive, once environmental factors, including water resource depletion are put into the accounts. Brown et al (2005) concur, and show that natural resource rich Queensland had a genuine savings rate of around half of the Australian average. However, neither HRT, Randall or Brown et al include a measure of technological change in their estimates of CI. In contrast, we include a proxy for technological progress in CI, based on the method suggested in Pezzey et al (2006), given the importance which other long-run analysis has shown of including such an adjustment (Greasley et al, 2014).

2. Australia as a case study

Australia attained world-leading incomes and consumption by the 1850s, but lost its exceptional position during the 20th century (Broadberry and Irwin, 2010, Madsen, 2015). At issue is whether or not a depletion of natural assets uncompensated by investment in other elements of the capital stock and a comparatively low CI contributed to this “lost exceptionalism”. Australia’s economy has long extracted natural resource rents (Cashin, 2002, Battelino, 2010). These rents have chiefly been gained from exploiting non-renewable minerals or finite pastoral land resources, against a backcloth of fast population growth.

As noted above, HRT emphasise the “missed opportunities” of natural resource abundant countries post-1970. Their counterfactuals show how the produced capital stocks of 70

resource-rich countries might have grown 1970-2000 had they adopted variants of the Hartwick rule. Most resource-rich developing countries did not attain their ‘generalized’ Hartwick rule of 5% genuine savings, and by implication actual produced capital stocks for most countries were lower than in the counterfactual world, creating a wedge between potential and actual consumption. However, Australia differs from many developing countries with regard to non-renewable resources. The rise and fall of public investment and swings in international borrowing have been distinctive elements of Australian produced capital formation (Maddock, 2015). Moreover, human and technological capital now form a large part of Australia’s wealth. Randall (2008) reports that intangible capital (calculated as a residual) comprised nearly 80% of Australia’s total wealth in 2000. Thus, HRT’s method of constructing counterfactuals, which simply consider the re-investment of resource rents in produced capital, are too restricted for Australia.

Further, simply re-investing resource rents, or, indeed attaining a 5% CI/GDP ratio, does not provide a sensible ‘rule of thumb’ for Australia, which experienced world-leading incomes and consumption for much of the post-1861 period. This is because leading economies have often attained savings ratios of above 5%. The counterfactual CI ratio used in our paper therefore uses the savings rates (rates of comprehensive investment) attained by other leading OECD countries over the past 150 years (Hanley et al, 2015) to calibrate what Australia might have saved and invested, and thus how much higher its present day wealth (future consumption possibilities) might have been today.

Constructing long series of CI for years since 1861 and investigating their correlation with the present value of consumption changes over horizons of 50 years into the future provides evidence to show the utility of CI as a consumption sustainability indicator for Australia. Several variants of CI are considered, including measures using total factor productivity to measure changes in technological capital. In most CI exercises, mining

production is a deduction from natural capital, but new mineral discoveries have been as much a characteristic of Australian mining as extraction, since finds often outpaced production (Wright and Czelusta, 2002). Our analysis of CI as an indicator of future changes in consumption thus also includes a variant which assumes that new minerals discoveries offset extraction over finite (50 years) time horizons. The various estimates of the CI and future consumption relationship are used to identify the appropriate counterfactual for gauging the feasible trajectory of Australia’s consumption, had it matched OECD rates of CI, to gauge whether or not Australia is indeed a land of missed opportunities.

3. Comprehensive investment and future consumption

Ferreira, Hamilton and Vincent (2008), hereafter FHV, showed that with a constant population growth rate of γ , a population at time t of N , a consumption discount rate of ρ , and year-on-year change in produced capital K , denoted \dot{K} , that per capita CI, denoted g (for genuine savings) is given by:

$$g = \frac{\dot{K}}{N} - F_R r - \gamma\omega \quad (1)$$

where $(F_R r)$ is the shadow value of per capita natural capital extraction and ω is per capita wealth, which is the sum of per capita natural and produced capital stocks W at time t divided by the population N . This shows CI per capita is determined by per capita net change in produced and natural capital (the first two terms on the right-hand side of equation (1) adjusted by a “wealth dilution effect” from population growth $-\gamma\omega$. Equation (1) thus shows the constituents of the CI indicator at any point in time.

Of equal interest is the theoretical literature which relates CI to changes in well-being into the future. For instance, Arrow et al (2012) show that intergenerational well-being is rising over future periods if CI is positive when evaluated at the correct shadow prices in the

current period. Hamilton and Withagen (2007) show that if CI is positive and growing at a slower rate over time than the real discount rate, then consumption will rise over time. FHV (2008) show that in any period t , the value of g is equal to the discounted value of changes in per capita consumption from t to infinity if the consumption discount rate ρ is adjusted downwards by the (constant) population growth rate. If population grows at a varying rate, then the relationship between per capita CI and the present value of changes in future consumption is altered. From this, FHV derive a reduced-form relationship between CI and the present value of changes in future consumption (PV ΔC) with constant population growth:

$$PV\Delta C_{it} = \beta_0 + \beta_1 g_{it} + \epsilon_{it} \quad (2)$$

or with varying population growth:

$$PV\Delta C_{it} + PV(\Delta\gamma_{it}\omega_{it}) = \beta_0 + \beta_1 g_{it} + \epsilon_{it} \quad (3)$$

Ferreira and Vincent (2005) was the first empirical test of CI as a forward-looking sustainability indicator. They used four alternative measures of changes in a country's capital: gross investment in produced capital; net investment in produced capital; net investment adjusted for depletion of natural capital (green net savings), and finally green net savings augmented by investment in education. A test of CI as a predictor of future changes in consumption is that $\beta_1 = 1$. They found that β_1 is always positive except for a sub sample of 22 OECD countries, a finding they attribute to the likely greater importance of technology or total factor productivity in developed countries. FHV (2008) estimated both (2) and (3) using data for 64 developing countries over the period 1970-2003. Their chief finding is that the hypothesis $\beta_1 > 0$ is supported only for green net savings and its varying population growth adjusted equivalent. However, their estimates of β_1 are "significantly below 1".

Greasley et al (2014) and Hanley et al (2015) extend tests of the CI by using longer spans of data, covering up to 250 years for Great Britain, Germany and the USA. They additionally

investigate the effects of allowing for a “value of time passing”; treating time as an uncontrolled capital stock, that, through exogenous technological progress, expands the economy’s production possibilities, following Pezzey (2004). Thus, in the terminology of (2) and (3), g can now include changes in both human capital and a value of technological progress as increments to the capital stock, as well as changes in produced and natural capital. The hypothesis of a one to one relation ($\beta_1=1$) between the more inclusive (value of technology-augmented) measures of net investment and future well-being over horizons of up to 100 years receives some support from their findings for Great Britain. Additionally, for a 3-country panel of Germany, the USA and Great Britain with post-1870 data for consumption per capita and CI measures augmented with the value of technology, these authors report estimates of $\beta_1 = 1.12$ and 1.16 , for horizons of 50 years, depending on the inclusion or otherwise of fixed effects in the panel regressions. Moreover, they find evidence of cointegration between CI and the PV of future consumption, indicating that current period CI can be a good predictor of future consumption.

3.1 Comprehensive Investment and Australia

Now we turn to formulating the CI measures used to indicate future changes in Australia’s consumption for years since 1861. Several measures of Australia’s CI per capita are used here to represent g in the empirical tests of Equations 2 and 3. The motivation of the tests is to establish how the alternative measure of CI indicate changes in the future consumption of Australia since 1861. The hypothesis $\beta_1 = 1$ provides the basis for gauging the utility of the CI measures as an indicator of changes in future consumption in Australia, assessed here over forward-looking horizons of up to 50 years.

An important consideration for the Australian CI estimates arises in the treatment of minerals in the natural capital stock measures, which form part of green net savings and varying population growth-adjusted green savings. Previous studies (e.g. Hamilton and Clemens, 1999; Hanley et al, 2015) simply treat mining as capital depletion, but new discoveries of economically viable resources are potentially an important increment to Australia's capital stocks. In recent decades, the discovery of new economically-viable reserves of many minerals have exceeded rates of extraction. In the absence of historical data on viable reserves, the alternative investment measures used here either count or omit mining as capital depletion, to gauge which approach best indicates future consumption changes. Moreover, technological progress has been a powerful long run force in raising incomes and consumption in developed countries (Abramovitz, 1956). Pemberton and Ulph (2001) and Pezzey et al. (2006) have highlighted the need to include changes in technology in measures of a nation's capital stocks. Weitzman (1997) suggested the incremental value of technological change for a nation's total capital could be as high as 40% of Net National Product. Since omitting a technological progress measure may understate changes in capital, especially for OECD countries, variants of CI augmented with a technology premium based on total factor productivity are also reported and utilized here.

Accordingly, the results in section 5 use eight alternative measures of g_t :

1. NP, which is net national investment in produced capital;
2. GreenI, which comprises NP plus changes in natural capital, where mineral extraction is equated to depletion;
3. CI, which comprises GreenI and education investment;
4. CIm, which is CI, adjusted for the value of mineral extraction;

5. CITFP, which is CI augmented by a value for changes in exogenous technological progress;
6. CImTFP, which is CIm augmented by a value for changes in exogenous technological progress;
7. CITFPW, which comprises CITFP adjusted for the wealth dilution associated with a varying population growth; and
8. CImTFPW, which comprises CImTFP adjusted for the wealth dilution associated with a varying population growth.

These eight variables are described in the Data section 4, and used in tests of the hypothesis $\beta_1 = 1$, in the Results section 5. Having gauged the utility of the various savings measures as forward looking indicators of Australia's consumption, section 6 then reports a counterfactual experiment to show a trajectory of consumption in a world where Australia matches the investment of Germany, the USA and Britain over the period 1870-2011, rather than investing at observed historical rates.

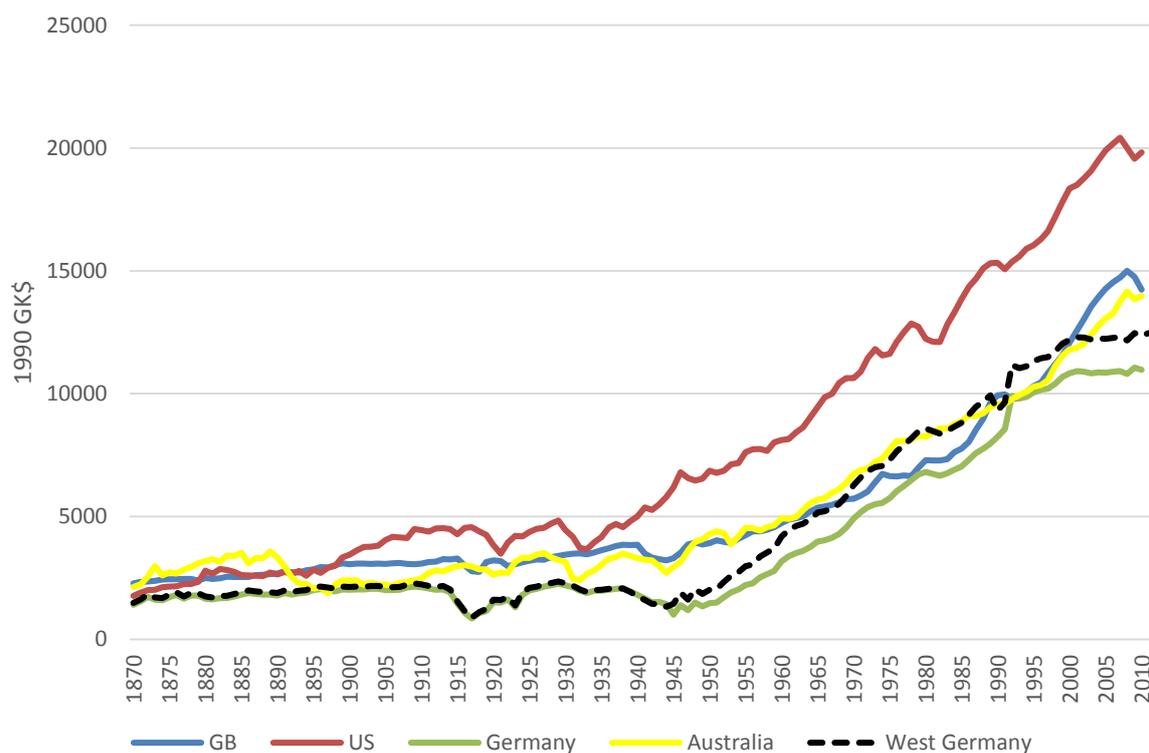
4. Measuring Australia's Comprehensive Investment and Consumption

4.1 Consumption per capita

Australia's average consumption per capita was exceptionally high by the early 1870s, and was around 12% higher than that of the UK over the years 1870-4, when measured in (purchasing power adjusted), denoted \$GK. The disparity in 1870-4 with the USA and Germany was even greater, with Australian advantages of 35% and 68% respectively. Most analysts attribute this "Australian exceptionalism" to the high productivity of the pastoral and minerals economy (Broadberry and Irwin, 2007). However, compared to the most prosperous

parts of the world Australia has experienced consumption decline since the 1870s, most obviously relatively to the USA, as shown in Figure 1. British and Australian consumption per capita have aligned more closely since the 1870s, but the long phase of higher Australia levels post-1945 ended around 1990. Germany's relative position is impacted by the effects of the world wars, but, along with the UK, Germany catches up with Australian consumption levels in the 1990s, although reunification hits average German consumption thereafter.

Figure 1. Consumption per capita (\$GK, 1990)

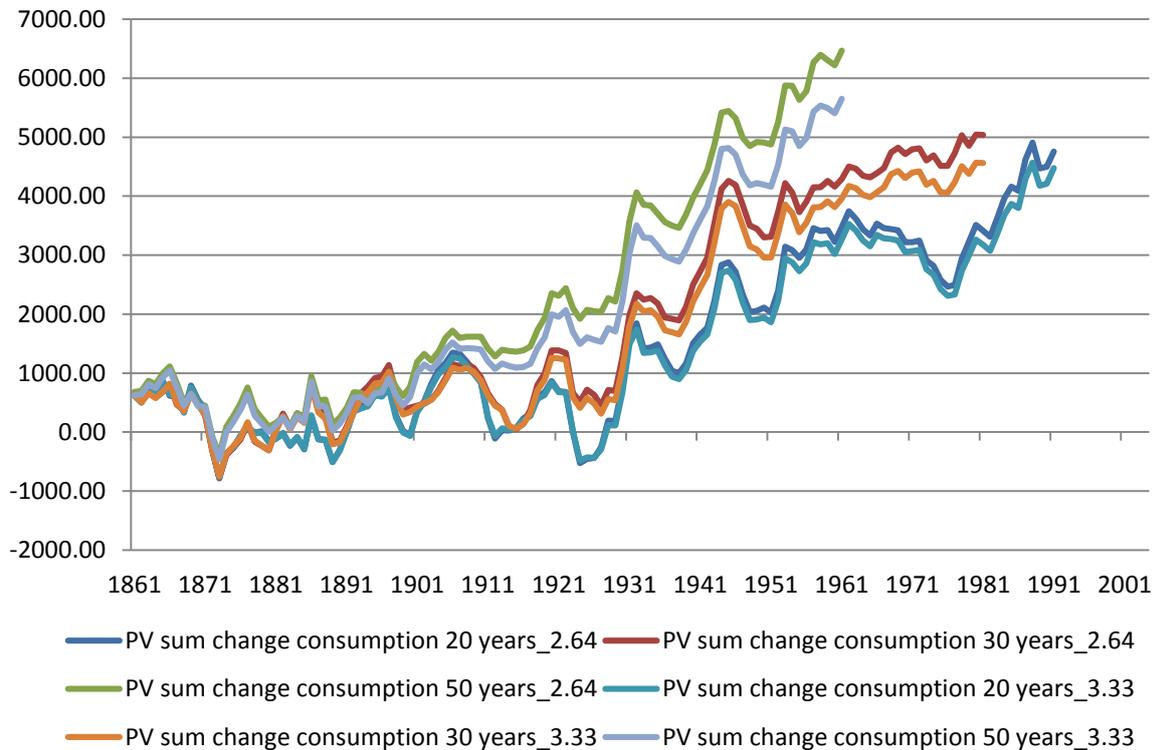


The central issue for us is whether or not this comparative decline in Australian consumption levels could have been avoided with higher savings. The PV of future changes in Australian consumption per capita in \$A, for horizons of between 20-50 years using alternative discount rates, are shown as Figure 2. The discount rate of 2.64%/year is the

average long-run interest rate (Pope 1986, Homer & Sylla 2005, OECD) minus the CPI inflation rate from 1861-2011.¹ Thus, for example, the final data point for the 50 years' horizon is 1961, with consumption changes measured over 1961-2011. The series show that consumption per capita generally rises, especially in the 20th century, although over the shortest 20 years' horizon negative changes are experienced until the 1920s, with consumption per capita falling 1927-47.

The next step in gauging if any of the eight alternative investment measures, g_t , are good indicators of the changes in future consumption is to test the relationship of our various measures of savings to changes in future consumption.

Figure 2: PV of changes in consumption (\$A, 1990)



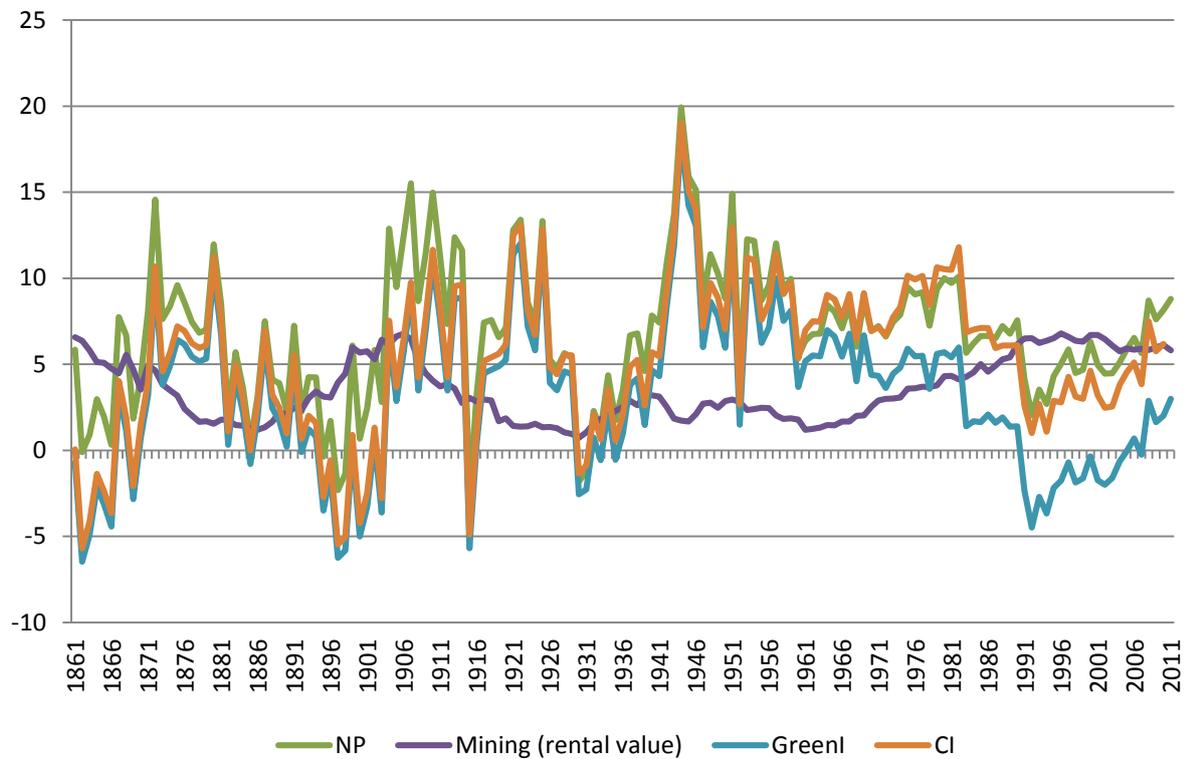
Kozack (2005) considers possible criteria for choosing the discount rate. One alternative is to use a discount rate which will reflect the fundamentals of country's capacity to consume, for example exports or GDP. Australia's average growth rate of real GDP averaged 3.33%/year from 1861 to 2011. This higher discount rate is used as a sensitivity test in the Results section, and the data are also shown in Figure 2.

4.2 Produced, Green and Education Investment

Estimates of Australia's net national produced investment, NP, are extant for years from 1861 (Butlin, 1962, ABS cat. no. 5206). The chief additional elements in GreenI are the increments in the rental value of land and the extracted value of mining rents. Pastoral land accounts for the bulk of farmland rents in Australia. Butlin's investment accounts reflect the importance of cattle and most especially sheep farming in Australia by incorporating livestock accumulation. His sequence of net domestic capital formation, plus livestock accumulation, less net overseas borrowing leads to a concept of net national capital accumulation (Butlin, 1962, p. 5). Livestock have been an important part of Australia's assets, and the changes in their stocks were large compared to net investment in produced capital in the 19th century. The annual gain from livestock accumulation averaged 1.05% of GDP 1861-90 (Butlin, 1962, pp. 62-7). The value of livestock's accumulation mirrors closely the changes in the rental value of pastoral land (Greasley, 2015, p. 163). Accordingly, the estimates of livestock accumulation are used here to approximate changes in pastoral rents since nomadic pastoralism, especially in the earlier years, makes measuring pasture in use problematical. The land area under cultivation each year can be measured directly. Rental values per hectare of agricultural land are higher than for pasture, but cultivated land rent's contribution to overall land rents is relatively modest (Greasley, 2015, p. 164).

The estimates of NP incorporating livestock accumulation, shown in Figure 3, averaged 6.82% of GDP 1861-2011. NP was sometimes negative, most especially in the 1890s and the early 1930s. The highest rates of NP were achieved in the decade before World War One, and during World War Two and the 1950s. Australia's domestic produced investment (not shown) was sometime above NP, given the sometimes high level of overseas borrowing, for example during the 1870s and 1880s.

Figure 3: Comprehensive Investment (% GDP)



Australia has long extracted mineral rents, defined here as minerals production multiplied by price less wage costs per ton. Following the gold boom of the 1850s, there have been three periods when mining rents exceeded 5% of GDP: during the 1860s, around the turn of the twentieth century and since 1988. Over the long period mining rents averaged 3.53% of GDP. Debiting minerals extraction and adding changes in cultivated land rentals from and to NP yields the series GreenI in Figure 3. This measure of Australia's green investment averaged 3.29% of GDP 1861-2011, showing that Australia most likely surpassed the 'Hartwick Rule'. Some elements of natural capital, most especially the net loss of forests, are omitted from GreenI due to a lack of data, but they are unlikely to overturn the finding that Australia, over the long run, re-invested the rents from using natural resources. Randall (2008) and Brown et al (2005) concur that deforestation is modest after 1970. There are only conjectures of the

likely forest area for earlier years, notably those of Gammage (2011) which argue that afforestation accompanied the decline of the aboriginal population.

There are, however, prolonged periods where GreenI is negative, including between 1991-2007, during the earlier mining booms of the 1860s, and around the turn of the twentieth century. For the years to World War Two, CI and GreenI align closely, given low education investment. Thus, Australia's CI was also negative for long periods before 1939; on several occasions by amounts in excess of 5% of GDP. In contrast, the higher rates of education investment after 1945 have been associated with consistently positive CI, contributing to an average CI/GDP ratio of 5.28% in the period 1861-2011.

4.3 Augmenting Comprehensive Investment with Technology.

Weitzman (1997) and Pemberton and Ulph (2011) advocated including exogenous technological progress in the capital stock assessments of a country. Arrow et al (2012) also included the value of technological progress as part of a country's capital stock. Pezzey (2004) refers to such technological progress as part of a "value of time passing", which increases the future consumption possibilities of an economy. The case for including exogenous technological progress within a more comprehensive investment measure appears strong for OECD countries where residual productivity plays a central role in income growth (Manuelli and Seshadri, 2014).

Trend growth TFP estimates underpin the valuation of exogenous technological progress. Treating time as an uncontrolled capital stock means TFP's contribution to the change in wealth in any year should be included in the augmented measure of CI. Our approach to gauging how TFP contributes to changes in the value of wealth follows Pezzey et al (2006,

Equation 14) and calculates the present value of future changes in TFP over a 20 year horizons, using a 2.64% per annum discount rate.²

The TFP index utilized here includes inputs of pastoral land, approximated by the stock of sheep and cattle, and hectares of cultivated land (Greasley and Madsen, 2016). Accordingly:

$$TFP = Y/K^{\alpha}T^{\beta}L^{1-\alpha-\beta}, \quad (5)$$

where Y is real GDP, K is produced capital, T is pastoral and agricultural land, L is labor hours, and the exponents are the relevant output elasticity, measured by income shares.

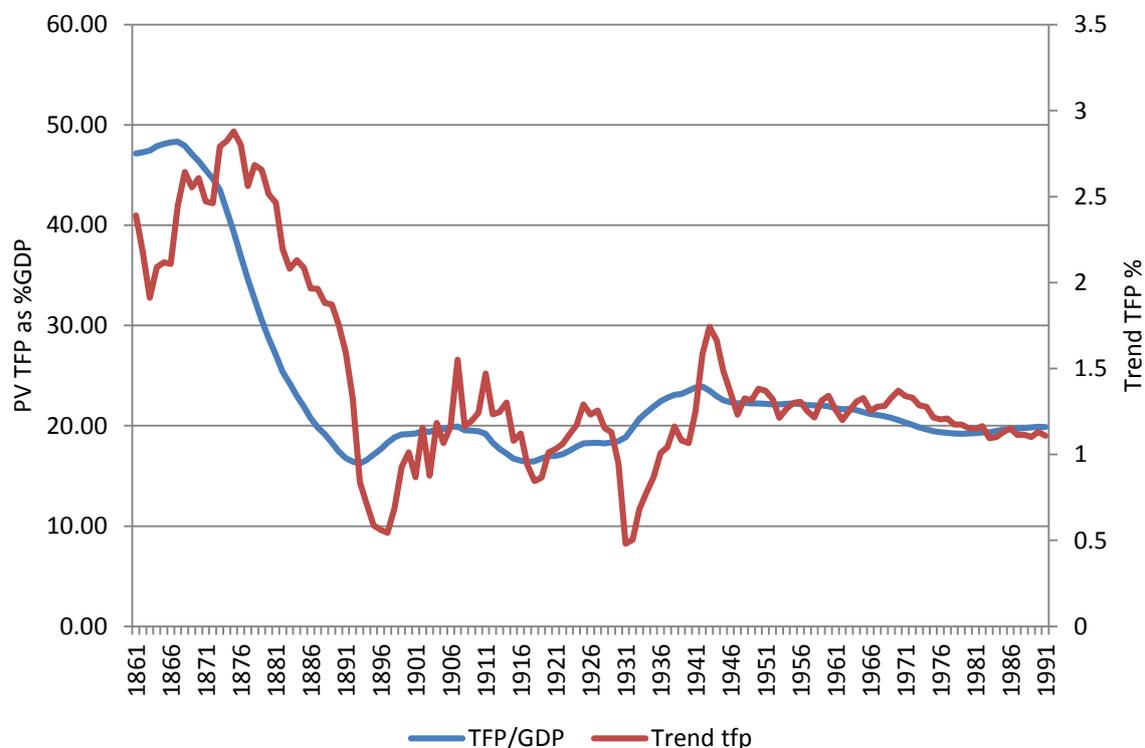
The treatment of minerals, specifically the exclusion of reserves as a factor input, needs to be explained. Over time the extraction of minerals will diminish the reserve, to the likely detriment of measured TFP (Syed, Grafton and Kalirajan, 2013). Alternatively, discoveries in Australia, most often of gold before 1914, but of a wider range of minerals from the 1960s, including iron ore and bauxite tempered depletion, to likely augment measured TFP. Thus the index of TFP, which shows actual average growth of 1.57% per annum 1842-90 and 0.79% per annum 1891-2009 is a residual which may reflect, inter alia, the vagaries of minerals discoveries. Greasley and Madsen (2016) report an adjusted measure of TFP, allowing for variations in mineral endowments per worker hour, which shows 0.66% per annum average growth 1842-2009.

The measures of CI including technological change used here (CITFP) incorporates a measure of trend TFP (extracted using a Kalman Filter) using data defined as Equation 5, and illustrated in Figure 4. TFP unadjusted for minerals reserves is adopted because TFP from any source will impinge upon future consumption. Moreover, the measures of CITFP

² Except where a 3.33%/year discount rate is used for consumption and then a 3.33%/year discount rate is also used for the value of TFP.

available for the comparator countries are also unadjusted for mineral reserves, thus the counterfactuals reported in section 6 need to be based on consistent data. The measure of trend TFP, therefore, is not strictly exogenous technological progress, the uncontrolled stock of technological capital associated with the ‘passing of time’, but rather reflects wider forces influencing residual productivity.

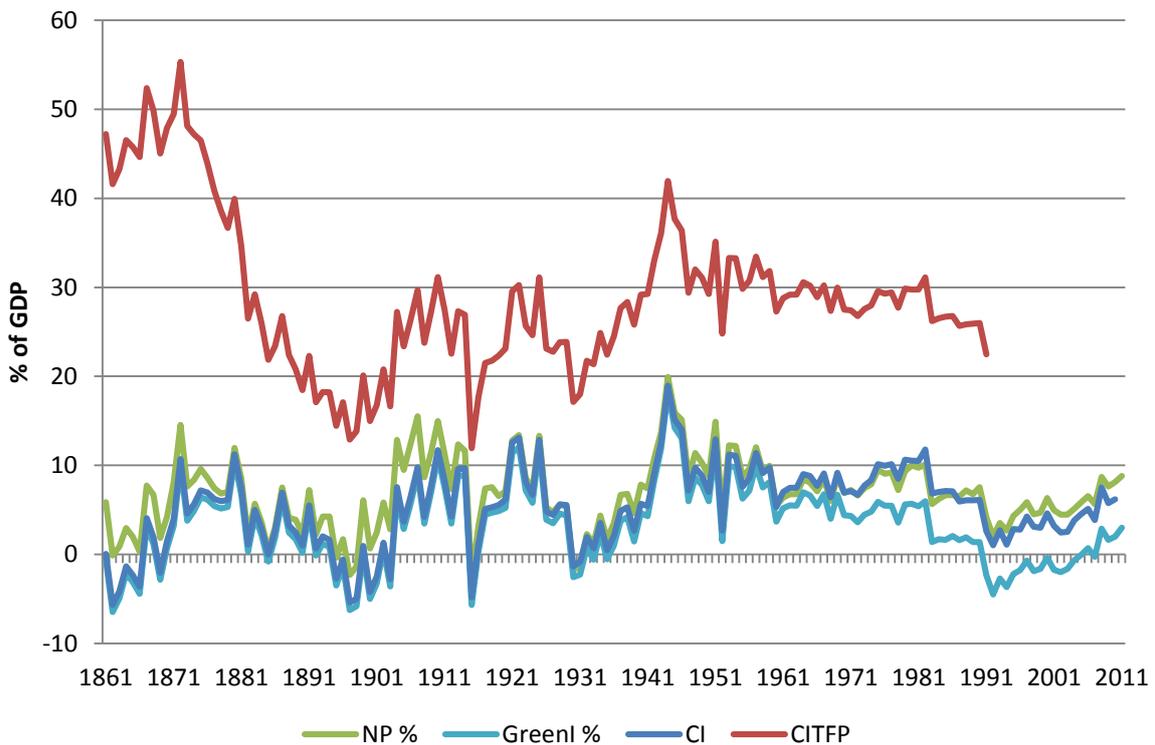
Figure 4: Trend TFP and PV TFP/GDP



The present value of TFP summed over a 20 years’ horizon and discounted at 2.64% per annum averaged around 20% of annual GDP since the 1890s, and it was higher in earlier decades, see Figure 4. These data highlight the magnitude of TFP for changes in the comprehensive wealth of Australia. To illustrate, Figure 5 compares NP, GreenI, and CI with the TFP augmented measure, CITFP. Whereas CI averaged around 5% of GDP, the

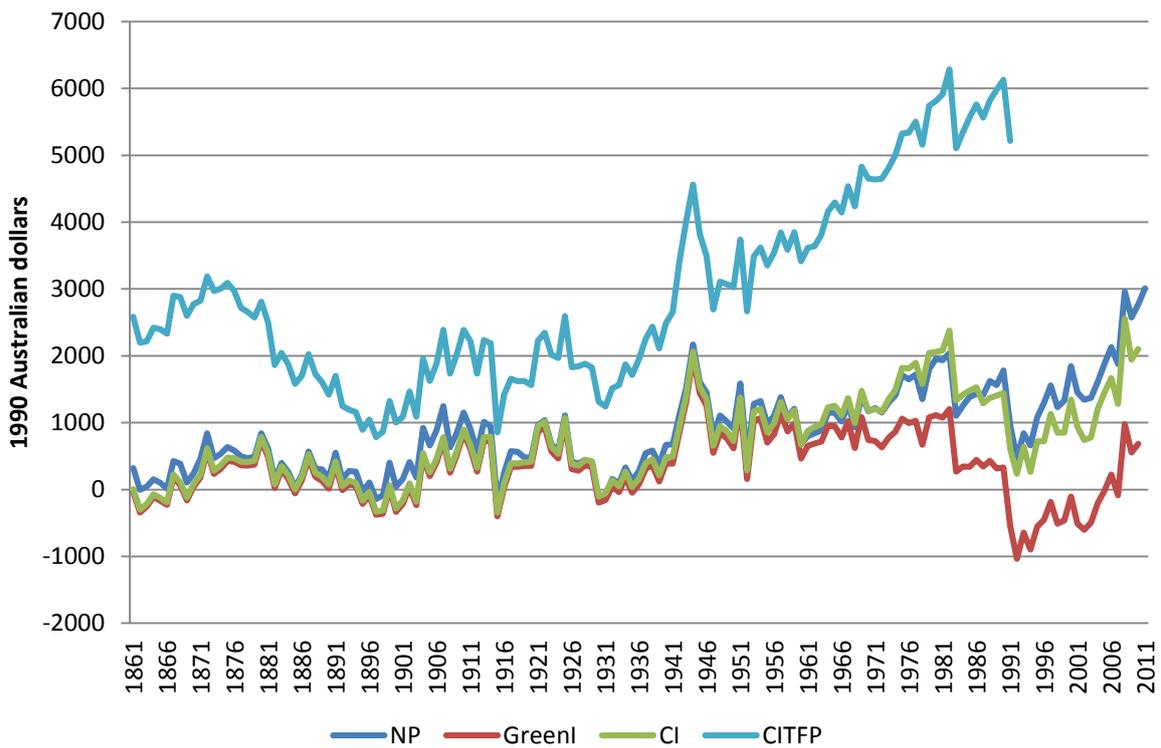
corresponding figure for CITFP is around 30%. These comparisons highlight the central influence of technological change and the other ingredients of residual productivity for rich countries like Australia, and temper the value of HRT-type 5% genuine savings prescriptions for OECD, and possibly for developing, countries.

Figure 5. Alternative Investment Measures



Although the ratio of CITFP/GDP peaked in the 1870s and again after 1945, real CITFP per capita shows an upward movement though the 20th century, see Figure 6. While GreenI per capita is often negative, the values of CITFP per capita are consistently positive and generally rising. Intuitively at least, the positive changes in the PV of future consumption per capita shown in Figure 2 correspond generally with the upward shifts in CITFP per capita. The precise relationship is estimated in section 5.

Figure 6. Alternative Investment Measures per capita (\$A, 1990)



4.4 Varying population growth and wealth-dilution.

With varying population growth FHV (2008) show that the relation between CI and the present value of future changes in consumption is altered by a wealth dilution effect (equation 3 above). The wealth dilution effect arises from the sharing of a given amount of capital between more people. So long as population growth is positive, wealth dilution reduces CI per capita, The measure of aggregate wealth used here to calculate the wealth dilution effect follows the World Bank’s ‘top-down’ construction method. The World Bank measure identifies Total Wealth with the present value of an estimated stream of private and public consumption over 25 years. On this basis Australia’s wealth per capita shows no appreciable gain from the 1860s to around the years of World War Two. Since then wealth per capita has grown by a factor of three.

5. Estimation and Results of hypothesis tests on β_1

The long time series for the alternative measures of g , used in the estimation of Equations 2 and 3, have the potential to exhibit non-stationary properties. Thus, without appropriate methods, the estimates may be inefficient or spurious and the usual significance tests may be invalid (Engle and Granger, 1987, Greasley and Oxley, 2010). A cointegration estimation approach as used here: (i) it resolves the problem of non-stationary time series data and the inference issues of its neglect, (ii) has the interpretation that the cointegrating relationship (if it exists) can be regarded as a (potentially) unique long-run economic equilibrium relationship, (iii) has the properties that the estimates are 'super-consistent' i.e. they are consistent with much smaller sample sizes, (iv) 'washes-out' in the long-run random errors that may exist in one or both series and, (v) means inferences can be made on the levels of the series. If cointegration exists, the power of its long-run properties, which are the chief interest here, will dominate short-run variations, which by definition are stationary.

The tests for the existence of cointegration use the Engle-Granger (1987) 'two-step' approach which appraises the time series properties of the residuals in a levels OLS regression and where the null hypothesis is of no-cointegration. It should be stressed however, that a case of non-cointegration does not necessarily invalidate the results, but they are less robust.

Consider first the results for NP, GreenI, CI and CIm reported in Table 1, where the estimates of β_1 fall in the range of 2.5-2.6. The proposition $\beta_1=1$ underpins the empirical tests of CI as an indicator of future consumption, as explained in Section 3. In all four cases the hypothesis $\beta_1=1$ is rejected for our data, so that the PV of future changes in real consumption per capita over a 50 years' horizon is higher than that indicated by the level of savings. These results also temper the utility of adjusting conventional net produced

investment with broader measures of natural and human capital formation for understanding Australia's consumption per capita since 1870. Thus, the measure of GreenI, which counts mining as disinvestment, has an estimated β_1 close to that for NP, despite Australia's substantial extraction of minerals. Moreover, CI which augments GreenI with education investment and CIm, which does not count mining as disinvestment, have similar estimated coefficients. The message appears clear enough: over the long run, the augmented measures GreenI and CI do not better indicate future changes in consumption than NP, and all the measures *not* augmented with a value of technological progress greatly understate future consumption growth. Of course, these results need to be judged in the context of the ADF tests which do not reject the null of no-cointegration in the cases of NP, GreenI, CI and CIm.

What appears more relevant for Australia is the augmenting of the investment series with a technology premium. In this case, for CITFP and CImTFP the estimated β_1 parameter values are 1.34 and 1.31 respectively, and, in the latter case, the null of a one to one relationship between investment and future changes in consumption, looking forward fifty years, is not rejected. The results for CImTFP raise the possibilities that extracting minerals should not be counted as disinvestment and that Australia consumed exhaustible natural capital to support consumption, to the possible detriment of future generations. However, the longevity and the discovery of new mineral reserves in Australia casts some doubt of accounting conventions which simply equate extraction with disinvestment, and we return to this issue later. More certainly, technological change formed an important part of changes in Australia's wealth, and its value needs to be incorporated in interpretations of future consumption growth. However, once again, in the absence of cointegration, the estimated long run coefficients of β_1 in the cases of CITFP and CImTFP need to be treated with some caution.

Table 1. OLS Estimates of Equation 2 β_0 and β_1 (2.64% per annum discount rate)						
Dependent	Independent	β_0	β_1	$\beta_1=1$	$\beta_0=0$ & $\beta_1=1$	ADF
CONS50	NP	790.04*	2.500*	17.72*	124.4*	-2.33
		(259.9)	(0.355)	(0.00)	(0.00)	
CONS50	GreenI	1328.9*	2.544*	18.58*	156.9*	-2.41
		(203.6)	(0.358)	(0.00)	(0.00)	
CONS50	CI	1098.1*	2.64*	24.83*	164.2*	-2.75
		(207.5)	(0.328)	(0.00)	(0.00)	
CONS50	CI _m	534.2*	2.60*	23.91*	130.1*	-2.68
		(262.3)	(0.327)	(0.00)	(0.00)	
CONS50	CITFP	-820.3**	1.339*	3.07**	3.17	-1.52
		(468.4)	(0.193)	(0.08)	(0.21)	
CONS50	CI _m TFP	-1047.8*	1.310*	2.61	5.45**	-1.48
		(506.2)	(0.191)	(0.11)	(0.06)	

Notes: CONS50=Net Present Value of Consumption per capita for 50 year horizons, * and ** denote significant at the 5 and 10% level respectively.

A characteristic of Australia since 1870 has been its high population growth, which has exceeded the rates of Western Europe and the USA. Thus, the possibility of a significant wealth dilution effect (the spreading of capital among a larger population), may have particular resonance for Australia. The estimates, for the technology augmented measures in Table 2, are based on Equation 3, which adjusts the savings-consumption relationship for possible wealth dilution. The form of the adjustment includes a wealth-related variable on both sides of the equation, hence we report OLS and 2SLS estimates, where the latter are deployed to counter any possible bias from endogeneity. In all four cases the estimated β_1 value is not statistically significantly different from unity. These findings reinforce the argument for a technology premium to be included in the measure of savings, but also that

wealth dilution associated with population growth was a drag on Australia's consumption growth. The robustness of these findings is strengthened by the rejection of no-cointegration.

The inclusion, or otherwise, of minerals extraction as disinvestment has very little effect on the estimated relationships. In the case of the 2SLS point estimates, β_1 is respectively 1.22 and 1.20 with and without the inclusion of mining as disinvestment. This does not mean that attempts to include natural capital within investment accounts are without merit. While GreenI here includes the rental value of farm land and mineral extraction, the accounting exercises of Carter et al (2005) and Randall (2008) further consider forest depletion, water quality and pollution. We are unable to measure these variables with pre-1970 data, and the effects of their exclusion are uncertain, so their omission might lead to an overstatement of rises in wealth. Yet the point estimates of β_1 all exceed unity. If anything, the wealth dilution-adjusted estimates suggest that our broadest measure of savings, CImTFPW understates changes in wealth, at least in the context of understanding consumption changes over finite horizons of up to 50 years ahead.

Table 2 OLS and 2SLS Estimates of Equation 3 β_0 and β_1 (technology-augmented investment series including wealth dilution effects)

Dependent	Independent	β_0	β_1	$\beta_1=1$	$\beta_0=0$ & $\beta_1=1$	ADF
OLS						
CONSWP50	CITFPW	5012.0*	1.096*	0.418	215.4*	-3.79*
		(442.5)	(0.147)	(0.518)	(0.00)	
2SLS						
CONSWP50	CITFPW	5324.1*	1.216*	1.36	113.7*	-5.94*
		(445.8)	(0.151)	(0.18)	(0.00)	
OLS						
CONSWP50	ClmTFPW	4776.8*	1.101*	0.47	198.0*	-3.83*
		(418.4)	(0.146)	(0.49)	(0.00)	
2SLS						
CONSWP50	ClmTFPW	5027.1*	1.201*	1.84	105.1*	-6.02*
		(419.1)	(0.148)	(0.18)	(0.00)	

CONSWP50 = $PV\Delta C_t + PV(\Delta\gamma_t\omega_t)$. Discount rate = 2.64%/year minus population growth rate.
 Instruments used: dependent variable (-1); labour; capital; population; year; rate of interest (short).

There are other possibilities as to why the point estimates of β_1 in Table 2 all exceed unity. These include that the wealth dilution effects of population growth are overstated, or that the consumption discount rate is understated. Much of Australia's population growth since 1870 has been from immigration, and to the extent that the migrants embodied human capital not measured in the Australian national accounts, changes in its wealth might be understated in the accounting of CI. The consumption discount rate embedded in the estimates of Tables 1 and 2 is the *ex post* long run interest rate. To the extent that uncertainty surrounding the future might influence current consumption decisions this rate might understate the value of immediate consumption. The results in Table 3 incorporate a higher discount rate of 3.33%/year (less the population growth rate), which reflects Australia's long run capacity to consume, measured by real GDP growth. The effect is to reduce the point estimates of β_1 to values very close to unity. Another feature of the results in Table 3 is that

the OLS and 2SLS estimated parameter values of β_1 are much closer than for the results in Table 2 with the lower discount rate. Again, the results which count or exclude mining output as capital depletion show little material difference.

Table 3 OLS and 2SLS Estimates of Equation 3 β_0 and β_1 (technology-augmented investment series including wealth dilution)

Dependent	Independent	β_0	β_1	$\beta_1=1$	$\beta_0=0$ & $\beta_1=1$	ADF
OLS						
CONSWP50	CITFPW	4085.7*	1.029*	0.220	234.5*	-6.44*
		(326.4)	(0.135)	(0.83)	(0.00)	
2SLS						
CONSWP50	CITFPW	4441.0*	0.990*	0.01	299.9*	-6.17*
		(334.4)	(0.118)	(0.93)	(0.00)	
OLS						
CONSWP50	ClmTFPW	4309.9*	1.026*	0.04	258.6*	-6.31*
		(347.3)	(0.136)	(0.85)	(0.00)	
2SLS						
CONSWP50	ClmTFPW	362.4*	1.022*	2.62	184.4*	-11.6*
		(32.1)	(0.013)	(0.11)	(0.00)	

CONSWP50= $PV\Delta C_t + PV(\Delta\gamma_t\omega_t)$. Discount rate = 3.33%/year minus population growth rate.

Instruments used: dependent variable (-1); labour; capital; population; year; rate of interest (short).

6. Counterfactual Australia: comparisons with OECD countries

The statistical tests do not reject the hypothesis that CITFPW and ClmTFPW exhibit a one to one relationship with the PV of future changes in Australia's consumption per capita for horizons of 50 years. Cointegration tests imply that Comprehensive Investment, as measured at time t, is thus a predictor of future changes in consumption. We utilize this finding, along with earlier results for Britain, the USA and Germany, to explore what might have happened to the trajectory of Australia's consumption had Australia's savings matched that of the other countries. The chief elements in the savings ratios of the four countries are set out in Table 4.

Australia, since 1946, has had the lowest CI ratio of the four. Its NP after 1946 exceeds that of Britain, but Australia's higher depletion of natural capital and slightly lower education investment accounts for its lower CI. The three comparator (using West German data) countries CI ratio averaged 9.91% between 1946-2000, which is 33% higher than Australia's ratio. The augmented ratio CITFP is also lower in Australia after 1946. The three country ratio averaged 38.4% between 1946-2000, which is around 32% higher than Australia's CITFP ratio of 29.11%. The implication is that, on both the simple measure (CI) and the technology adjusted measure (CITFP), Britain, Germany and the USA achieved savings rates averaging around one-third higher than those of Australia after 1946. The consequences for Australia's comparative consumption decline after 1946 appear to have been ameliorated (over a finite 50 years' horizons) by consuming natural capital, according to the CImTFP measure, since not debiting mineral use adds 4.04% to the saving rate 1946-2011.

Table 4 Savings Ratios as a per cent of GDP, and population growth rates

	I	II	III	IV	V	VI	VII
	<i>NP</i>	<i>GreenI</i>	<i>CI</i>	<i>CITFP*</i>	<i>CImTFP*</i>	<i>PVTFP*</i>	<i>Population</i>
	%	%	%	%	%	%	% per annum
	1870-2000						
<i>Britain</i>	5.40	3.53	5.71	25.62		19.94	0.62
<i>Germany</i>	10.00	8.78	11.59	45.40		33.81	0.64
<i>W. Germany</i>	10.00	9.27	12.19	46.00		33.81	0.81
<i>US</i>	9.81	7.12	10.26	37.62		27.36	1.52
<i>Australia</i>	7.12	3.93	5.81	27.85	30.78	21.99	1.93
<i>Australia 1861-2011</i>	6.83	3.28	5.29	29.12	32.22	23.78	2.00
	1946-2000						
<i>Britain</i>	6.29	4.43	8.07	35.77		27.35	0.33
<i>Germany</i>	9.35	8.16	12.36	49.83		37.47	0.53
<i>W. Germany</i>	9.35	9.35	13.46	50.94		37.48	0.63
<i>US</i>	5.37	2.97	8.20	32.41		24.21	1.28
<i>Australia</i>	7.75	4.11	7.42	29.26	32.27	21.69	1.75
<i>Australia 1946-2011</i>	7.52	3.44	6.97	29.26	32.27	22.14	1.70
	1870-1990						
<i>Britain</i>	5.50	3.63	5.68	25.57		19.90	0.54
<i>Germany</i>	10.32	9.00	11.70	46.22		34.52	0.35
<i>W. Germany</i>	10.32	9.54	12.38	46.90		34.52	0.83
<i>US</i>	10.44	7.65	10.55	40.16		29.61	1.39
<i>Australia</i>	7.35	4.43	6.06	27.85	30.78	21.79	1.72
<i>Australia 1861-1990</i>	7.04	3.92	5.52	29.12	32.22	23.55	2.11

* Present value of TFP is discounted over a 20 year horizon, the data in columns IV-VI are averages ending in the year 1991

Over a longer period since 1870, Australia's CI ratio also aligned closely with that of Britain, but lagged well behind the US and German ratios, which averaged a 9.38% CI ratio between 1870-2000, some 60% above Australia's ratio. For the technology-augmented CITFP ratio the three country average over the longer period is 36.5%, or 31% above Australia's ratio. Together, the comparative data for the post-1946 and post-1870 periods highlight that Australia's savings have been persistently low compared to our comparator countries, and that all measures of savings (NP, CI and CITFP), contributed to the shortfalls. Again, the consumption of natural capital appears to have tempered the relative decline of Australia's consumption over the 50 years' horizon, with CImTFP showing a 3.1% higher savings rate than CITFP between 1861-2011.

Next we consider the possible extent of lost consumption arising from Australia's relatively low savings since 1870. Before doing so, we note that Australia savings rate was only low relative to the comparator countries used here. Compared to developing, natural resource rich countries, Australia's savings rates are deeply impressive. HRT's generalized 'Hartwick rule' postulates that a 5% genuine savings ratio may lead to unbounded consumption, and they highlight the failure of many natural resource rich countries to meet this rule post 1970. Our measure which corresponds most closely with HRT's genuine savings data is CI, and for Australia we estimate a CI/GDP ratio of 5.29% for the period 1861-2011. The CI ratio markedly understates the savings of Australia, since it excludes a value for technological progress's contribution to the stock of wealth. On the wider CITFP measure Australia's savings ratio averaged around 29% between 1861 and 2011. Concomitantly, the real value of Australia's consumption per capita grew around seven times over the same period, despite a wealth dilution effect due to the population growing by a factor of around 19. However, the other OECD countries attained CITFP ratios which averaged around 31% higher, despite lower population growth, which again points to missed

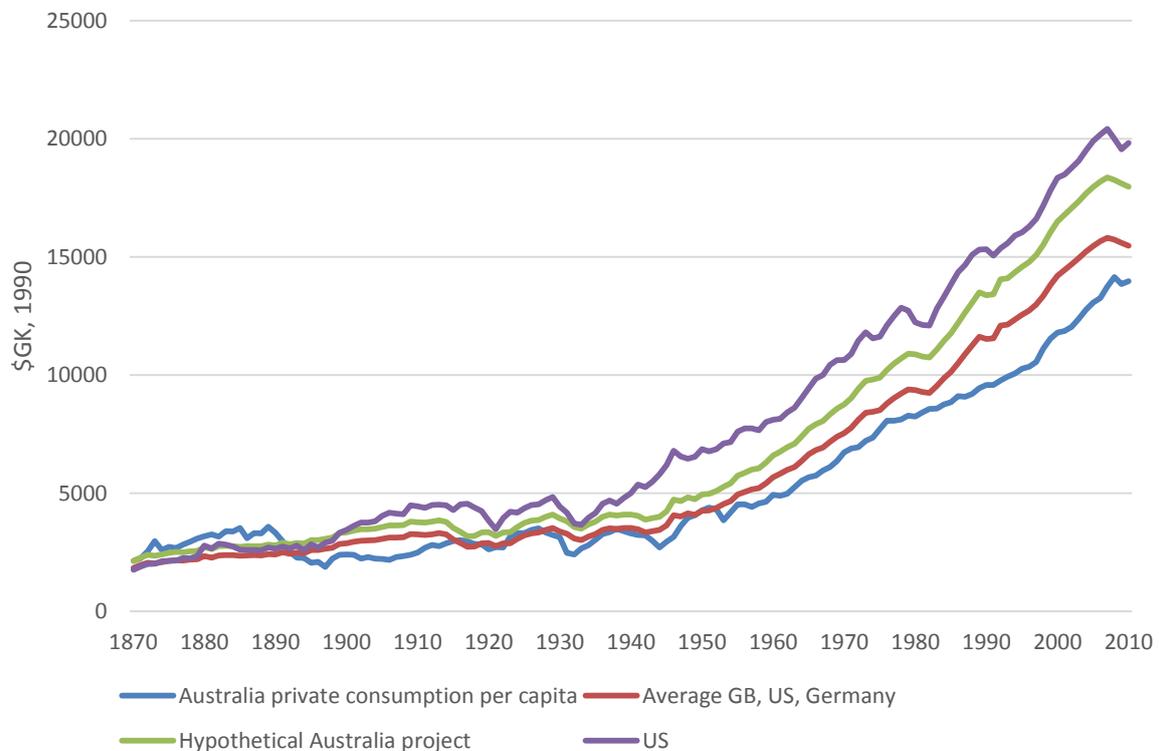
Australian consumption opportunities. Even if we postulate that Australia had greater capacity to support consumption over finite horizons by consuming natural capital, the CImTFP measure shows an 1861-2011 savings rate of around 32% which falls short of the average 36.5% CITFP of the comparator countries. At best, consuming natural capital only ameliorated the pace of Australia's relative consumption decline.

Had Australia, post-1870, matched the average CITFP of Britain, Germany and the USA, its consumption would at least have matched the average consumption growth of the comparators. We have shown elsewhere (Hanley et al, 2015) that CITFP provides a good, near one to one, indicator of future changes in consumption of the three comparator countries since 1870, over horizons of up to 50 years. The estimates of β_1 for Australian CITFP are also not statistically different from unity, once allowance is made for wealth dilution from population growth, and these results hold with the alternative measures of the discount rate. For Australia, CImTFP, where mining output is not debited in the savings measure, also provides a near one to one indicator of future consumption over a 50 year's horizon. Thus, Australia's consumption growth may have exceeded that of the other three countries had it simply matched their average CITFP, because of a greater capacity to consume natural capital.

A projection from Australia's actual consumption per capita in 1870, (Figure 7) shows a counterfactual trajectory, assuming Australia had indeed matched the average consumption growth of the OECD comparators. The counterfactual shows that Australia consumption per capita would have been around 28% higher by 2010 had its CI been equal to that of the comparator countries. The counterfactual shows a potential for Australia's consumption to have *sustained* a distinct margin above that of the leading European economies, which was forgone because of Australia's relatively low savings. Thus, in 2010, counterfactual

Australian consumption per capita is 26% above British, and 44% above West German levels. These are large losses by any standards.

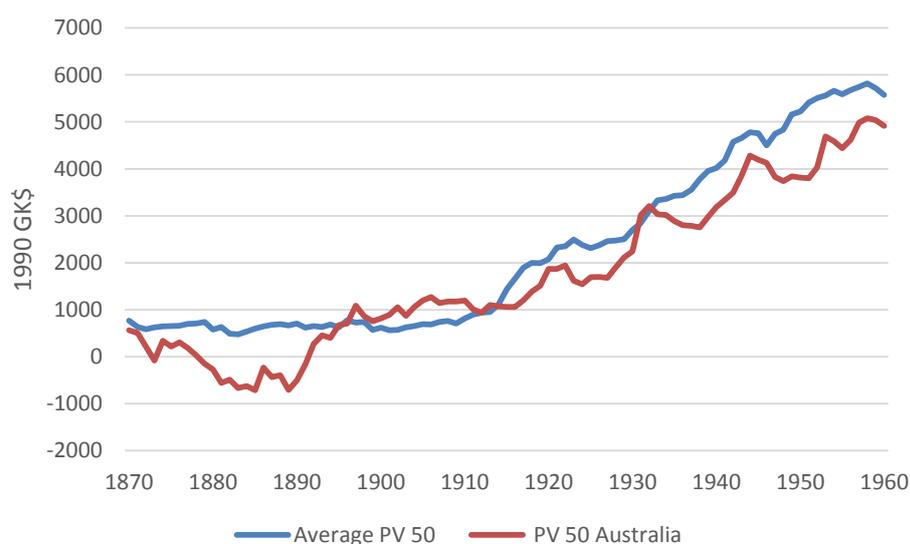
Figure 7. Consumption per capita (\$GK, 1990)



The erosion of Australia’s world leading consumption per capita levels of the early 1870s was not a smooth process. An illustration is provided by Figure 8, which show the discounted PV of consumption per capita changes over 50 year periods. In 1870, the (discounted) value of the change in Australia’s consumption per capita over the next 50 years (PVΔC50) was \$GK566, which, we have argued, reflects the value of CITFP or CImTFP in 1870. Thereafter, Australia’s PVΔC50 fell sharply and was negative between 1879-1891. It was not until 1897 that Australia PVΔC50 shows levels above the comparator countries average PVΔC50. By implication, a long phase of relatively low Australian saving spanning the years 1870-1896 diminished relative Australian consumption growth over a period lasting until 1946.

Unusually, Australia's $PV\Delta C50$ exceeds the three country average between 1897-1913. These were years of higher Australian savings, see Figures 5 and 6, with produced investment showing a sharp rise during the first decade of the twentieth century. This helped to moderate the gap between Australian and the comparator countries consumption growth through the 1950s. However, Australia pre-1914 savings upturn was short lived, and was choked-off, initially by World War One and the interwar depression. Post-1945, CITFP growth was less strong in Australia, and the gaps between Australia's and the other countries $PV\Delta C50$ persist to present day.

Figure 8: PV of future changes in consumption (\$GK, 1990)



Note: The discount rate for Australia is 2.64%/year. Other countries discount rates are from Hanley et al (2016).

7. Concluding remarks

Comprehensive Investment (Genuine Savings) has become the most widely-used economic indicator of sustainable development (World Bank, 2011; UNEP, 2014). This indicator focusses on how well a country maintains its asset base of all forms of capital over time,

taking into account how the rents from natural resource exploitation are utilized as consumption or savings. The issues are important for Australia's political economy, given its high endowments of natural resources per capita. The standard World Bank savings indicators do not place Australia in favourable light, at least compared to other OECD countries. Moreover, others, including Brown et al (2005) and Randall (2008) have suggested that the World Bank indicators may overstate Australia's genuine savings, by understating its depletion of natural capital. The issues, however, are complex and Brown et al also note that new discoveries of minerals in Queensland have created reserves, of for example coal, which may last 600 years. Nevertheless, there is a growing concern that Australia's savings have been inadequate (McLean, 2013). The establishment of nation building wealth funds in 2008 to support investment in infrastructure, health and education illustrates one policy response to these widely-held concerns (Australian Government Future Fund, 2014).

This paper's principal contributions are fourfold. Firstly, estimates of Australia's comprehensive investment have been pushed back to 1870, and compared to the long run data for the USA, Britain and Germany. Secondly, these measure of savings have been extended to include a value of technological progress. Thirdly, the utility of comprehensive saving measures as predictors of future changes in consumption over a 50 year's horizons for Australia has been gauged. Fourthly, we have explored how the trajectory of Australia's consumption per capita would have grown after 1870, had it matched the savings of comparator OECD countries, to gauge Australia's "lost opportunities".

Australia's comprehensive investment as reported here has been positive in most years since 1870, even without allowing for a value of technological progress. A genuine savings ratio averaging around 5% of GDP, which is probably what Australia has attained since 1870, is sufficient to meet HRT's generalized 'Hartwick' rule for unbounded consumption over time. However, the growth of Australia's consumption after 1870 has, from the tests reported

here, greatly exceeded what would follow from a 5% savings rate. Much of the discussion surrounding the utility of comprehensive investment as an indicator of weak sustainability surrounds the possibility that natural capital depletion is understated in the empirical estimates. Brown et al (2005) show, for example, that coral and water resource degradation may not be reflected in the accounts. Certainly, the historical data constructed here does not fully reflect all changes in natural capital. Yet, without allowing for a value of technological progress, the measures of comprehensive investment grossly understate future consumption, looking forward 50 years. However, when allowance is made for productivity advances, the technology augmented measure of savings indicate the future changes in consumption remarkably closely.

Now, this does not mean that incorporating changes in natural capital in measures of savings is unimportant. On the contrary, some forms of natural capital depletion may have implications for strong sustainability, and these ought to be measured. The impact at the local level of natural capital depletion, for tourism or agriculture, for example in Queensland or the Murray Darling Basin, might also be substantial. However, the results here show clearly that productivity improvements have been the chief driver of Australia's consumption growth since 1870. Thus, any attempts by policy makers to manage the natural capital stock, need also consider the implications for technological progress. In the case of minerals extraction, the World Bank's accounting methods would suggest a capital depletion averaging around 3% of GDP in Australia since 1861. In contrast, the results suggest a value of technological progress's contribution to wealth which averaged around 23% of GDP between 1861 and 1990. Within the context of weak sustainability, this technology premium clearly dominates natural capital depreciation, which has led to sustained and substantial growth of consumption, despite a rapid population growth.

Within the assumptions of the weak sustainability model on which Comprehensive Investment is based, Australia can readily consume natural capital and maintain consumption growth, so long as sufficiently-rapid technological progress is maintained. Even in the context of strong sustainability, certain forms of natural capital depletion including minerals extraction, may have little economic relevance, given the remaining lifetimes of reserves at current extraction rates. The results here, however, reveal some real concerns about Australia's savings rate when compared to other OECD countries. In common with previous studies we also find that Australia's comprehensive investment has not matched that of other developed countries, a conclusion that applies to most years since 1870. The underpinnings of relatively low savings in Australia appear to be broadly based, and to span produced, human and technological capital. To an extent Australia's greater capacity to consume natural capital has probably ameliorated the pace of relative consumption decline. Even so, we show, on conservative assumptions, that Australia consumption per capita might have been 28% higher by 2010, had it matched the savings rates of leading OECD countries since 1870. Had this higher savings rate been realized, Australia would have maintained the per capita advantage in consumption which it had over western European countries more than 100 years ago.

Data appendix

Australia

GDP and GDP deflator:

Hutchinson (2016)

Consumption:

Post-1974 data are from the ABS (various dates), cat. no. 5204.0, expenditure on Gross Domestic Product. From **1901-1974** we use ANA 119-129, main expenditure aggregates, current prices (Vamplew, 1987). For **1861-1900** we back project from 1901 using data on GDP minus investment [ANA 98-103], and public services [ANA 50-64], (Vamplew, 1987), plus net exports [Appendix Table 3 Exports, Imports, Openness and Current Account deficit], Ville and Withers (2015).

Discount rates:

We use the average long-run real interest rate as our discount rate, this is 2.64%/year. Data on nominal interest rates are from Pope (1986), Homer & Sylla (2005), and OECD. For real rates we subtract the average CPI inflation rate for 1861-2011 (Hutchinson 2016). We also use an alternative discount rate of 3.33%/year which is the long-run average real GDP growth rate (Hutchinson 2016).

Population:

Hutchinson (2016)

NP: net national Investment in produced capital

NP is calculated by subtracting capital depreciation and net capital outflows from gross capital formation, following the approach of Hamilton and Clemens (1999, 342).

Gross capital formation: 1960-2010 cat. no. 5204.0 Australian System of National Accounts, Table 2. Expenditure on Gross Domestic Product, ABS (various dates). **1861-1960** series: Vamplew (1987), Table ANA 65-71 - Gross private capital formation, current prices, 1861-1939; Table ANA 79 Livestock accumulation, current prices; Gross domestic capital formation, public and private, Australia 1861-1900; ANA 119-129 Main expenditure aggregates, current prices, Australia, 1901-1974.

Net Capital Outflows: 1960-2010 series: ABS (various dates), cat. no. 5204.0 Australian System of National Accounts, Table 2. Expenditure on Gross Domestic Product (GDP). **1861-1960** series: Vamplew (1987), ANA 80-81 Investment income due to non-residents and current account balance, current prices, 1861-1939; ANA 98-103; ITFC 84-100 Balance of payments current account 1901-1945; ITFC 182-199 Balance of payments current account, 1946-1981.

Capital Depreciation: 1960-2010, ABS (various dates), cat. no. 5204.0 Australian System of National Accounts, Table 2. Expenditure on Gross Domestic Product (GDP). **1861-1938** Butlin (1962). 1939-1959, in the absence of direct estimates, the average rate of the years 1935-39 is used for these years.

Green Investment: NP plus changes in natural capital

Changes in natural capital include agricultural, mineral and pastoral land rents.

Agricultural Land: 1982-2010: Land Use for Crop Production; Agricultural Commodity Statistics 2010, Dept. of Agriculture, Fisheries and Forestry. **1861-1981**: Vamplew (1987) series, AG 19-27 Land use colonies, states and territories. Hectares of cultivated land are

converted to rental values with land values from Taylor (1992) for the years to 1913, and rents taken as 10% of the capital values. Post-1913 rents per hectare are projected with estimates of international wheat prices (Carter et al, 2006, series Da717-729 and US Department of Agriculture).

Minerals:

The rents of minerals are calculated by subtracting labour costs from the market value of mining activities. The mining series are from the following:

Market value 1982-2011: from ABS(various dates), cat. no. 5206.0. **1861-1981:** Vamplew (1987), series, ANA 50-64, GDP by industry, current prices, 1861-1939. Series: ME 1-6, Gold production, 1851-1982; ME 13-16, production of iron, steel, and manganese, 1870-1983; ME 17-24, production of aluminium, nickel, titanium, zirconium and uranium, 1927-1983; ME 25-33, Coal production and exports; ME34-38 Petroleum production and imports, 1964-1983; ME 72-76, value of mineral production, exports and imports 1948-1983.

Labour force: 1982-2011: ABS (various dates), cat. no. 6202.0. **1861-1981:** Vamplew (1987), series: LAB 1-14, Workforce, colonies 1841-1901; LAB 15-31, Workforce, 1911-1981; LAB 33-49, occupations; LAB 50-58, Average annual employment by industry, 1891-1979; LAB 50-58, Average annual employment by industry, 1891-1979.

Wages: Wage data from Hutchinson (2016) and from Vamplew (1987), series: LAB 155-170 Standard weekly hours of work of male adults, by industry, 1914-1980; LAB 110-115 Indexes of weekly wages, colonies and states, 1861-1914 ; LAB 116-123 minimum weekly wage of male adults, colonies and states, 1891-1984; LAB 124-142 Minimum weekly wage of male adults by industry, 1891-1980 ; LAB 153-154 average weekly earnings by gender 1946-1981; Lab 181-185 Average annual earnings in manufacturing, colonies, 1861-1900; LAB 186-194

Average annual earnings in manufacturing 1969-1982; LAB 195 - 208 average annual earnings in manufacturing 1909-1968.

Pastoral Land:

Estimates of pastoral land in use are unreliable given the often nomadic character of sheep farming. Livestock accumulation provides an alternative route to measuring changes in the rental value of pastoral land, to the extent that the animal carrying capacity of the land mirrors rents (Butlin, 1962, 62-7, Greasley, 2015, 162-3). The sources of the livestock accumulation data used to approximate pastoral land rents are as for gross capital formation.

Comprehensive Investment: GreenI and education investment

Education

Data on education expenditure is primarily from Vamlew (1987), series: SW 36-47, State and Commonwealth social welfare current expenditure, 1900/01-1977/78, and World Bank database 1978-2010. In order to assess the consistency of these data we made reference to other datasets including Tanzi and Schuknecht (2000), table II.5, public expenditure on education, Bourke and Spaul (2001), table C7.1. However, for the period **1861-1900** no consistent data was available, therefore we assume that education expenditure was a constant rate of 0.78% of GDP which is based on the average of 1900-1910 estimates.

Total Factor Productivity

The annual index of TFP is from Greasley and Madsen (2016, Equation 1) using their preferred TFP (BDL) variant. Trend growth of these data for each year 1861-2010 is extracted using a Kalman Filter and used to construct a measure of the value of technological progress. We use the present value of future changes in TFP over 20 horizons with 2.64%/year and

3.33%/year discount rates to value technological progress, where the discount rates are matched with those for consumption.

Wealth:

Wealth is calculated as the net present value of public and private consumption over 25 years.

Where public and private consumption calculated as a residual from GDP (Hutchinson (2016)) minus investment and net exports (sources as for NP above).

Germany, Great Britain and the USA.

The data sources for the comparator OECD countries may be found in the Data Appendix of Hanley, N., Oxley, L., Greasley, D., McLaughlin, E., and Blum, M. (2016).

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