Genuine Savings as a Test of New Zealand Weak Sustainability

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Abstract: The key aims of this paper are to: i) to extend the World Bank's (WB) measure of Genuine Savings (GS) for New Zealand by using a longer time-series of data, 1950 – 2015; ii) improve GS estimates for New Zealand by adding additional dimensions to GS i.e. forestry; iii) investigate the relationship between several GS measures and the discounted values of GDP per capita and consumption per capita, used to proxy *well-being*; iv) test a series of hypotheses which relate GS to the change in future well-being using the framework proposed by (Ferreira, Hamilton, & Vincent, 2008) and v) investigate the effects of a growing population on the availability of future capital stocks by considering the consequences of 'wealth-dilution' as defined by Ferreira, et. al., (2008). The paper makes a contribution to the literature on GS, particularly in the context of New Zealand, by considering patterns of GS and well-being over a longer time span of data than has been previously used and adds to a relatively small, but growing literature on tests of GS using long- or relatively long- time series data (see e.g. Greasley, et. al., 2014; Greasley, et. al., 2017, Hanley, Oxley, Greasley, & Blum 2016). We conclude, based on the data used here, that *New Zealand's GS has been positive (i.e. weakly sustainable), since the start of our data series, even without allowing for the contribution of technological advancement.* However, *we also conclude that the effects of a growing population and a savings-gap, have lead to a 'wealth-dilution' effect needed to maintain real wealth per capita, as we estimate that there was an average savings gap (GS as a percentage of Gross National Savings) over the period 1955-2015 of 0.5% per annum.*

Keywords: Sustainability, Genuine Savings, Natural Capital, Hartwick Rule, New Zealand.

JEL classifications: Q01, Q25, Q56

Acknowledgements: The New Zealand Marsden Fund supported this research, for which we are appreciative. We wish to thank David Greasley, Matthias Blum and Nick Hanley for allowing us to use methods from our previously, published joint research and Tony Burton, Tim Ng (New Zealand Treasury), Adam Tipper (Statistics New Zealand) and Brett Longley (NZ Ministry of the Environment) for feedback, suggestions and support.

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1.0 Introduction: Genuine Savings as an Indicator of Sustainable Development

"Sustainability" is a concept that has attracted considerable attention over the year (see for example the bibliometric analysis by Qasim, 2017). Some of the ensuing discussions about whether countries are acting in a sustainable manner depend crucially on the specific notion(s) of sustainability that is/are being used, inferred or assumed.

The UN Sustainable Development Goals have brought the discussion of sustainable development to the attention of policy makers. One of the goals is the 'sustained, inclusive and sustainable economic growth'. Both the World Bank (2006, 2011, 2018) and the UNU-IHDP and UNEP (2012, 2014) have been torchbearers in measuring sustainable economic development from the approach of comprehensive/inclusive wealth and *changes* in wealth as opposed to income (GDP). Genuine Savings (GS), also referred to as Adjusted Net Savings (ANS), Comprehensive Investment (CI) and Inclusive Investment (II), has become one of the more commonly used indicators of sustainable development over the long-run (Arrow, Dasgupta, Goulder, Mumford, & Oleson, 2012, Blum et al., 2017a, Greasley et al., 2014a, Hamilton & Clemens, 1999, Pezzey, 2004)[1]. The most recent World Bank (2018) report highlights ANS trends across regions and publish summary tables by countries. However, given the widespread use of the GS indicator, legitimate tests of the approach have, until recently, been limited. The World Bank (2011, 2018), while updating wealth and ANS estimates, has not updated tests of this indicator since its 2005 Wealth of Nations report (World Bank 2006, chapter 6). The core contribution of this paper is to estimate Genuine Savings for New Zealand over the period 1950-2015. Given the quality and quantity of data available to measure NZ sustainability trends, New Zealand is surprisingly absent from these discussions – there is no mention of New Zealand in WB (2018). We will also add to the sparse empirical literature by applying the approach to tests of (weak) sustainability applied to New Zealand.

GS was first proposed by Pearce & Atkinson (1993) as an indicator of 'weak sustainability', based on the *Hartwick Rule* (Hartwick, 1977, 1990) according to which income from the use of non-renewable resources should be reinvested in renewable resources in order to

[1] For a 'primer' and partial survey of this literature see Oxley, L. (2017).

maintain total wealth and to achieve non-declining well-being over time. Following this framework, Pearce and Atkinson (Pearce & Atkinson, 1993, Pearce, Markandya, & Barbier, 1989) elaborated on the approach to suggest that ***an economy which saves more than the combined depreciation of its stocks of natural capital and produced capital*** will be (***weakly***) ***sustainable***. Whenever GS takes negative values, it indicates that the economy is on an *unsustainable* (in terms of the Pearce et al. (1989), definitions) *development* path. According to Hamilton & Atkinson (2006), if the total wealth (sum of all types of capital stocks i.e. human capital, produced capital and natural) is related to social welfare, whatever sustainability definition is used, it necessarily involves the creation and maintenance of total wealth. In other words, non-declining per capita total wealth has to be maintained inter-generationally to realise sustainability (Dasgupta & Mäler, 2001[2]). Weak sustainability (WS), the underlying assumption of ***GS, shows how different types of capital are combined to produce a stream of total wealth over time*** (Hanley, Dupuy, & McLaughlin, 2015). Pearce et al. (1989) noted the extent to which natural resource depletion can be compensated for by the equivalent investment in human capital or produced capital leading to two cases for this intergenerational rule:

1. Sustainable development requires non-declining total wealth (*weak sustainability*)
2. Sustainable development requires non-declining natural wealth (*strong sustainability*)

The concept of weak sustainability is embedded in the argument that natural capital and produced capital are substitutable. The notion of weak sustainability emerged in the 1970s (Dietz & Neumayer, 2007) when neoclassical models of economic growth were extended to account for non-renewable natural capital as a factor of production (Dasgupta & Heal, 1974, Hartwick, 1977, Solow, 1974). These aggregate economic growth models account for the optimal use of income produced from the non-renewable resource extraction in order to establish a rule by how much of it to consume and how much should be reinvested in produced (or other forms of) capital for future consumption. The key question posed by these models was whether the optimal growth is sustainable in the sense of non-declining well-being which proved to be implausible in a model which includes non-renewable

[2] See Fenichel, E.P., and Abbott, J.K. (2014). for recent developments of the Dasgupta/Maler approach.

resource as a factor of production. It turns out that that consumption declines to zero in the long-run as a result of saving for optimal growth (Solow, 1974). It therefore becomes necessary to define rules for non-declining welfare over time based on the maintenance of natural capital, produced capital, human capital and social capital.

Hartwick (1977) developed a general rule that the rents produced from the depletion of the non-renewable resource should be reinvested in the produced capital. This could be considered as a ***general rule of weak sustainability where the rate of change of net capital investment, which includes gross investment in all types of capital, which is measurable and subtractable from depreciation or consumption, is not allowed to be become negative*** (Hamilton, 1994). Assuming substitutability between different types of capital stocks (i.e. produced, natural and human capital), ***GS measures year-on-year changes in total capital***. *A country is said to be sustainable if it maintains or increases the overall stocks of capital* (Pearce & Atkinson, 1993).

Hartwick's and Solow's models consider renewable and non-renewable resources within a Cobb-Douglas production function model which is characterized by a unitary and constant elasticity of substitution between all factors of production. In other words, it assumes that natural capital and produced capital are similar and substitutable. To validate this assumption, either of the following must hold: (i) *natural resources are abundant*; (ii) or the *elasticity of substitution between natural capital and produced capital is equal to or great than unity*; (iii) technological advancement can *boost productivity of natural capital at a higher rate than its depletion* (Dietz & Neumayer, 2007). In order to measure weak sustainability, we need to associate economic values to the reduction in the quantity of natural capital and to environmental degradation i.e. the economic cost of damage to the quality of natural capital. This will enable planners to correctly understand if the natural capital losses are being compensated equivalently or not. Commonly used measures of weak sustainability are: environmentally-adjusted net product; genuine savings (GS); measures of resource depletion; measures of environmental degradation; the index of sustainable economic welfare etc. (Asheim, 1994, Dietz & Neumayer, 2007, Pearce & Atkinson, 1993, Quiggin, 1997, Romero & Linares, 2014). Among these indicators, GS is a widely used indicator of sustainable development and long-term well-being with the World Bank publishing measures of GS for a panel of countries since 1970.

The key aims of this paper are to: i) to extend the World Bank's measure of GS for New Zealand by using longer time-series data – in our case the period 1950 – 2015; ii) improve GS estimates for New Zealand by adding the most relevant dimensions to GS i.e. forestry which is ignored in Work Bank's GS model; iii) investigate the relationship between several GS and discounted values of GDP per capita as a long-term well-being; iv) test a series of hypotheses which relate GS to the change in future well-being using the framework proposed by (Ferreira, Hamilton, & Vincent, 2008) and v) investigate the effects of a growing population on the availability of future capital stocks by considering the consequences of 'wealth-dilution' as defined by Ferreira, et. al., (2008). The paper makes a contribution to the literature on GS, particularly in the context of New Zealand, by considering patterns of GS and well-being over the relatively long-run compared to existing empirical studies which rely on much shorter time periods. The paper adds to a relatively small, but growing literature on tests of GS applied to countries in Oceania see for example, Brown et. al. (2005), to detailed country specific studies of GS (Pezzey et al. 2006; Ferreira & Moro 2011; Mota & Martins 2010) and in particular those using long- or relatively long- time series data (see e.g. Greasley, et. al. 2014; Greasley, et. al. 2017, Hanley, Oxley, Greasley, & Blum 2016) which is required by the theory, yet frequently not undertaken in the literature which concentrates more on short time scale or panel-based estimation (see Ferreira, Hamilton, & Vincent, 2008; Ferreira and Vincent, 2005).

The remainder of the paper is organized as follows. Section 2 describes the GS modelling framework, and the specific approach used in this paper. Section 3 describes the data used and their sources, and the range of specific models to be tested. Section 4 presents the empirical estimates including the results of undertaking the hypothesis tests defined in Sections 2 and 3. Finally, Section 5 provides a discussion of the results, some conclusions and suggestions for future research.

2.0 The Theory of Genuine Savings and Future Wellbeing.

The theoretical foundations of Genuine Savings are well-established, see Hanley et al (2015) for a review of the theoretical literature. In this study, we apply the theoretical framework of

Hamilton & Hartwick (2005a) using the empirical framework proposed by Ferreira et al. (2008), FHV hereafter.

The theoretical model (equation 1) shows how the future changes in well-being equals genuine savings:

$$\int_t^{\infty} \frac{\mathrm{d}c(v)}{\mathrm{d}v} e^{\int_t^v -(p(\tau)-\gamma)d\tau} = g(t) \qquad (1)$$

Where c is per capita consumption, γ is a constant population growth rate, ρ is a consumption discount rate, and g is genuine savings. A key point regarding this model is that it is set in infinite time. FHV extended this framework by outlining *g,* Genuine savings, as:

$$g = \dot{k} - F_R r - \gamma\omega \qquad (2)^3$$

Where $\dot{k}$ is the year on year change in capital per capita, $F_R r$ is the *shadow value* of natural capital extraction per capita and ω is wealth per capita. This relationship explains how GS is determined by the per capita net change in natural capital and produced capital (the first two terms on the right-hand side of equation (2) adjusted by a wealth "*wealth dilution effect*" from population growth $-\gamma\omega$. Equation (2) therefore shows the constituents of the measure of GS at any point in time.

The main theoretical relationship proposed by FHV is that in any period t, the value of g should be equal to the present values of changes in per capita consumption, from time t to infinity if the consumption discount rate ρ is adjusted downwards by the constant population growth rate (Dasgupta, 2001). If population grows at a variable rate, then the relationship between GS and the discounted values of changes in per capita consumption is also changed.

In a competitive economy, *the per capita rate of GS for country* i *at time* t *should be equal to the present value of future changes in per capita consumption adjusted for a term which*

[3] Ferreira, Hamilton and Vincent (2008) present as their equation 1 (as above), the infinite horizon version of the Genuine Savings relationship. The fact that the theoretical version relates to an infinite horizon reinforces why, in empirical models, longer time series data are likely to generate results more closely aligned to the theoretical underpinnings than those from short time series or small T panels.

shows the effects of population growth on per capita wealth – the "wealth dilution effect" with variable population growth rates.

2.1. The approach taken in this paper

We apply the FHV (2008) GS and future well-being framework proposed to the case of New Zealand. Our approach extends the World Bank work in a number of important ways.

Firstly, we use data from multiple resources in New Zealand, over an extended period of 1950 – 2015, to more closely approximate or proxy the definitions of the variables in the theoretical model (i.e. the longer horizon relates more to the infinite time setting in equation 1).

Secondly, we examined the effect of time as an uncontrolled capital stock through exogenous technological progress (using a measure of total factor productivity (TFP), which expands the production possibilities of the economy (Pezzey, Hanley, Turner, & Tinch, 2006)). One important contribution is that we matched time horizons applied to discount the TFP growth series with that of the dependent variable discussed in detail in the data section. In previous studies, this has been kept constant, for example, Pezzey et al. (2006), Greasley et al. (2014, 2017) and Blum, McLaughlin, & Hanley (2017b) and set at 20 years or 30 years in Hanley et al. (2016).

Thirdly, we captured changes in human capital through investments in education. According to Hamilton (2006), the process of development can be characterised as economies converting their natural capital into the other forms of capital e.g. human capital and/or produced capital. Similarly, the importance of human capital for long-term development, is also acknowledged by Arrow et al. (2012). It is widely accepted that the investments in human capital development has direct impact on productivity (Black & Lynch, 1996, Blundell et al., 1999, Gemmell, 1996) therefore many studies on economic growth has used expenditure on education as a proxy of human capital at national level. On the downside, however, this proxy might not capture individual's capacity to earn income, or capabilities to perform better at micro-level which has led to the development of alternative methods such as Sen's capability approach for individual level studies.

Fourthly, we tested two alternative indicators of future well-being: (i) ***changes in the present value of per capita consumption*** as in FHV***; and*** ***changes in per capita real GDP***. Hypothesis tests are conducted which impose a range of restrictions.

In particular, based on FHV, the key hypothesis tests related to determine whether the theoretical relationship between GS and future well-being hold are:

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

Where all terms are the same as in equation (2) except that g_{it}^{*} includes both changes in human capital and the value of exogenous technological progress as part of the capital stocks together with changes in natural capital and produced capital. For a non-constant population growth rates and wealth dilution effect, the related theoretical relationship becomes:

$$PV\Delta C_{it} + PV(\Delta\gamma_{it}\omega_{it}) = \beta_0 + \beta_1 g_{it}^{*} + \epsilon_{it} \quad (4)$$

Such that the hypotheses to test for equation (3) and (4) become:

H_1: $\beta_0 = 0 \ and \ \beta_1 = 1$ jointly

H_2: $\beta_0 = 0 \ and/or \ \beta_1 = 1$ independently

These tests are conducted over four different time horizons i.e. 10, 15, 20 and 30 years.

Hypotheses tests are initially[4] conducted based on equation (3) for a *set of increasingly comprehensive measures of capital stocks* for New Zealand. Changes in the present values of real GDP per capita and changes in the present value of consumption per capita, are tested as alternative measures of well-being.

Finally, we consider the effects of possible '***wealth-dilution'*** a la FHV, which involves estimation, and testing of equation (4).

2.2 Empirical literature

Genuine savings has been tested using this testing framework in a series of studies (see Hanley et al 2015 for a review). FV and FHV analyse short panels using World Bank data. FV

[4] Estimates and testing based on equation (4) are presented in section 2 below.

found that $H_1$is rejected for all definitions of net investment. For H_2 they showed that β_1 is always positive and its absolute value increases with the use of more comprehensive measures of capital stock, though it declines when expenditures on education are included in the model. They speculate this reflects the extent to which education expenditure is a weak proxy of changes in the stock of human capital. H_3 is not rejected. Finally, changing the time horizon to calculate present values from 10 years to 20 years results in higher values of β_1. FHV use a panel of developing countries and exclude education expenditures in genuine savings and use a 20-year horizon to discount changes in future consumption. In their work, they applied increasingly comprehensive measures of changes in a country's assets base i.e. gross savings, net savings (net investment in produced capital), green savings (net savings depletion of natural capital) and pollution adjusted savings (green savings adjusted by wealth dilution effect) as in Ferreira & Vincent (2005). The allowance for the wealth dilution effect is the key conceptual change over Ferreira & Vincent (2005). Their main finding was that the $\beta_1 > 0$ hypothesis is not rejected for only green savings and its population adjusted equivalent. However, estimates for β_1 remain significantly less than 1 for all models summarised in their Table 2, p. 243. They also suggested that there was a "lack of significant impact for the adjustment for wealth dilution" (p. 246).

Finally, a number of recent studies have extended the test of GS by using longer time series data. Greasley et al. (2014b) and Hanley, Oxley, Greasley, & Blum (2016) covered up to 250 years data for Great Britain, Germany, and USA. The key differences in terms of the genuine savings metric was the inclusion of changes in both human capital and a value of technological progress as increments to the capital stock (where they follow Pezzey (2004), by allowing for "the value of time passing" to be captured as an uncontrolled capital stock through exogenous technological progress, which expands the economy's production possibilities), as well as changes in the produced capital and natural capital. These studies found support for $\beta_1 > 0$ as the time horizon increased but only with the inclusion of a measure of the value of time (TFP growth as in this study). in their study for a panel of three countries, Hanley et al. (2016) found that with post-1870 data for consumption per capita, GS measures augmented with the value of technology, explained changes in consumption well. In particular, they estimated $\beta_1 = 1.12 \; and \; 1.16$ for horizons of 50 years depending on the inclusion or otherwise of the fixed effect in the panel regression models. Most recently, Greasley, Hanley, McLaughlin, & Oxley (2016) have tested GS for Australia for 141 years.

On the contrary Lindmark, Thu, & Stage (2018) rejected the weak sustainability hypothesis in their empirical study for Sweden and criticised GS as a forward-looking indicator for long-term sustainability.

3.0 Data, calculations and variable definitions

The results presented below are based on New Zealand time-series data, 1950 – 2015 compiled from several national databases and publications. Variables are described in detail with data sources and descriptive statistics in the data *Appendix*. As a starting point, we briefly compare our key statistics with corresponding measures of Adjusted Net Savings (ANS) available from the World Bank databank for New Zealand. Table 1 and Figure 1 below present some of those comparisons. This initial first step is important as an introduction as to why our results may differ from those previously published by the World Bank, in particular, in addition to a longer time span being covered in our work, we also use data that in some cases has been approximated, yet can now be better measured and we also include some important additional data (e.g. on forestry) that was omitted from the World Bank's earlier modelling and estimation.

The World Bank has been publishing annual GS rates for a panel of approximately 160 countries including New Zealand. We compare averages of key variables in the GS model based upon our and the World Bank's estimates, and present the results as Table 1, below. The mean values of gross capital formation, consumption of fixed capital, education expenditure, nominal GDP, and population are very similar with very small differences, whereas the mean values of the remaining variables are often quite different. Two key factors are responsible for these differences: firstly, different data sources; and secondly, slight differences in estimation methods. For example, our main data sources are New Zealand national statistical yearbooks and other national databases, whereas the World Bank's key data sources are international databases (see the *Appendix* for further details).

In addition, the World Bank's estimates for New Zealand do not include forestry in their GS model. The World Bank approach has been only to subtract for deforestation but to omit afforestation, the latter being relevant in the case in New Zealand. This decision to omit afforestation might be to maintain comparability between the panel of 160 countries or due to lack of data availability.

Table 1: Comparison of averages of key variables between our estimates and World Bank's estimates

Variable	**As mean percentage of nominal GDP (otherwise specified) Between 1972 – 2015**		**Comment on source**
	World Bank	**Our Estimates**	
Gross National Savings	23.89%	23.97%	Different data sources
Net National Savings	5.00%	9.06%	Different data sources
Gross capital formation	23.66%	23.63%	
Consumption of fixed capital	14.62%	14.57%	Different data sources
Minerals and Energy	0.86%	0.56%	Different data sources
Forestry	NA	3.11%	Different data sources
Education Expenditure	5.21%	5.30%	Different data sources
Mean of Nominal GDP (millions)	95,896	95,877	Different data sources
Mean of Population (millions)	3,65	3,66	Different data sources

We have complied two new measures, Net national savings minus rents (NNSNR) and Net national savings minus rents plus forestry (NNSF), discussed in more detail later, to take these missing forestry data into account. The incorporation of the missing forestry data plays a vital role in considering the sustainability of the New Zealand's economy and future wellbeing, as a whole.

From these data we construct increasingly comprehensive measures of savings (as potential predictors of future wellbeing.

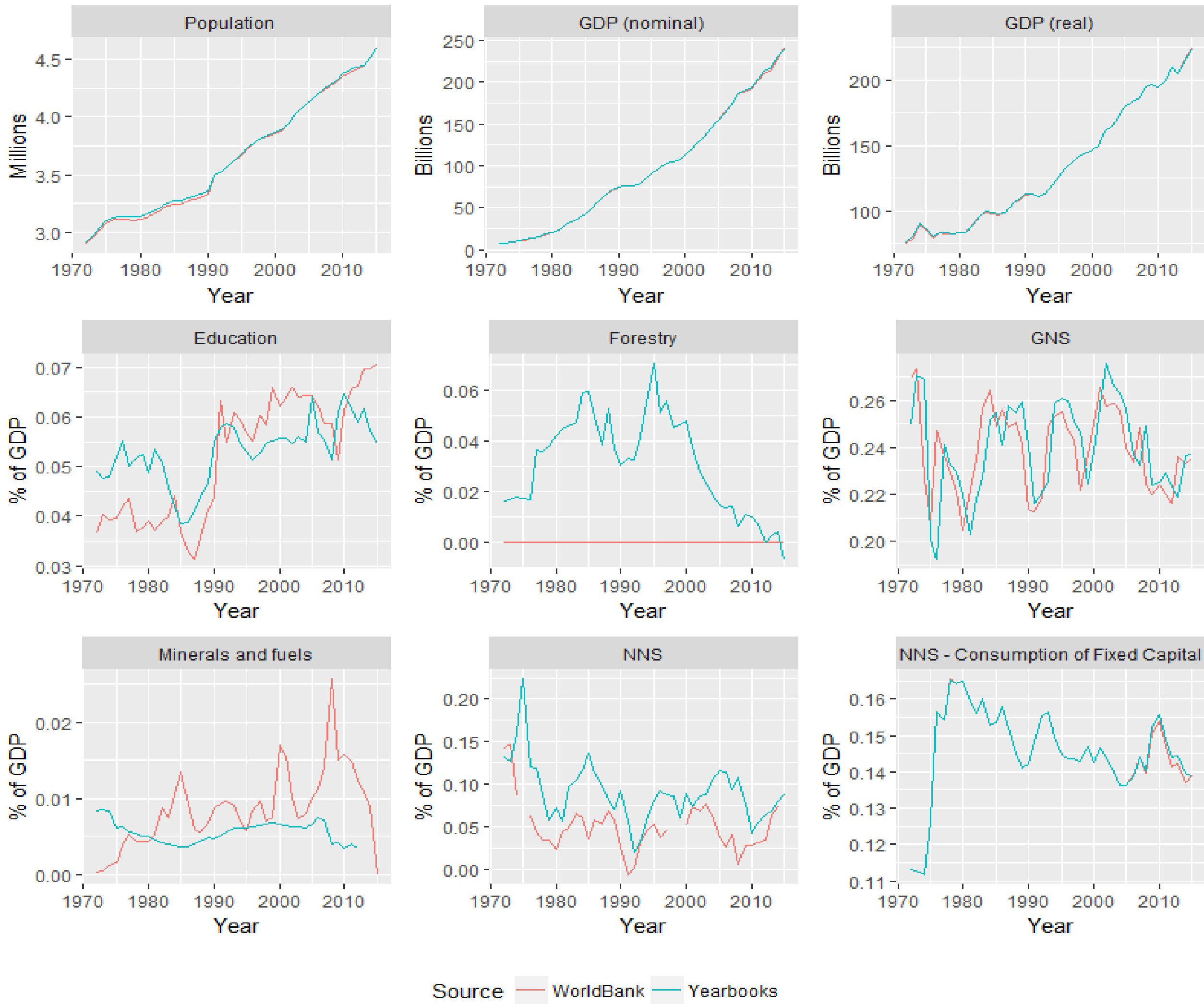
1. Net national savings (NNS)
2. Net national savings minus rents (NNSNR)
3. Net national savings minus rents plus forestry (NNSF)
4. Genuine savings (GS)
5. TFP growth series for NNSNR, NNSF and GS series

3.1 Net National Savings (NNS)

According to the World Bank methodology (Bolt, Matete, & Clemens, 2002), Gross National Savings (GNS) are calculated as the difference between gross national income and public and private consumption plus net current transfers (n.b. savings are seen as the 'residual' and not measured directly). NNS is calculated as the difference between gross national savings and depreciation/consumption of fixed capital (CFC). For this study, data for GNS and CFC are available from Statistics New Zealand (SNZ).

NNS exhibited a declining trend from the 1970s-1990s and subsequently a modest trend increase thereafter.

Figure 1: Time series comparisons of key variables between our estimates and World Bank's estimates



3.2 NNSNR

Our measure of NNSR is computed by the subtracting natural resource rents from NNS. Rents are obtained by subtracting average costs from market returns, this is standard framework for estimating resource rents (Bolt et al. (2002).[5] These rents are primarily derived from the mining of natural resources (excluding forestry) which include metals such as gold, silver, magnetite (iron) and non-metals rock, sand and gravel, limestone, amorphous silica, perlite, serpentine, silica sand, zeolite, iron ore, zinc etc.

Annual time-series data on the aggregate market value of all minerals are provided by: The *New Zealand Official Yearbooks*, NZOYBs hereafter, between 1950 – 1993; and by the *Mining Production Statistics* annual publications by the *Ministry of Business Innovation and Employment* (2000 – 2015). Six missing vales from 1994 – 1999 are imputed using linear extrapolations. Data for labour employed in the mining sector and their average wages are also extracted from NZOYBs. This allows our numerical estimate of GS, as far as NNSNR are concerned, to correspond with its theoretical equivalent, and this holds for the World Bank's estimates as well.

The New Zealand economy has benefited, in a GDP sense, from the extraction of non-renewable metal and mineral resources. There has been a rise in activity in the mining industry and in recent years this industry's contribution to GDP has risen by approximately 1 percent since 2007.

3.3 NNSF

This component of GS is estimated by adding to NNSNR the rents from forest depletion, which are excluded from the World Bank estimates for most of the countries they consider. In the case of New Zealand, the value assigned to forestry by the World Bank is set equal to zero for the whole period considered.

The volume of the standing forest includes the total area of both natural and planted forest in hectares. The volume of standing forest in cubic meters is estimated by multiplying the area covered by the forest (in hectares) by the average volume per hectare. These data were extracted from the *New Zealand Ministry of Primary Industries* in the *National Exotic Forest Description* (NEFD) and *Forest Owners Association* (FOA) facts and figures reports. The cost of production is estimated from the number of people employed in the forestry industry and

[5] See appendix for details on rent calculations.

the real wage, and market prices are determined by the average export price of all forest products from New Zealand available from NZOYBs.

Forestry is a significant industry in New Zealand as it has been contributing to an average of 3.4% of GDP annually over the period of this study, which is more than double that of the contribution to GDP from all other natural resources combined. Exports from forestry are estimated to reach $4.8 billion in 2017, which is almost triple of the all merchandised exports (NZIER, 2017).

In addition, New Zealand forests are a strong carbon sink (Hollinger, Maclaren, Beets, & Turland, 1993, Tate et al., 2000) which, from a New Zealand national accounting perspective, would offset the 'damages from carbon dioxide emissions' making these less relevant to our GS model.

3.4 Genuine Savings (GS)

GS is obtained from the sum of NNSF and investments in education as a proxy of human capital as per the World Bank methodology. Data for government spending on education at all levels (i.e. including primary, secondary, tertiary, etc.) are obtained from NZOYBs for the period 1950 – 1971 and from *SNZ* for 1972 – 2015. There are certain pros and cons of using education expenditure to a for proxy human capital. Government spending on education naturally fits into the GS framework, which articulates the varying components of investment. Nevertheless, human capital formation does not equate to spending on education (Hanley et al., 2016). For instance, human capital includes the skill set acquired in the workplace, voluntary online learning, etc. In addition, international migration of educated New Zealanders plays a vital role in terms of human capital available to the country. However, the brain drain from New Zealand is offset by the incoming professional immigrants to New Zealand, which many see as brain exchange, rather than brain drain (Glass, Choy, & others, 2001).

3.5 A Total Factor Productivity (TFP) growth series for the NNSNR, NNSF and GS measures: denoted NNSNRtp, NNSFtp and GStp

The inclusion of exogenous TFP growth (as a measure of ***technological progress*** denoted ***(tp***) into the assessment of a country's capital stocks has been advocated by many including

Pemberton & Ulph (2001) and Weitzman (1997). The underlying assumption of technological progress as an uncontrolled stock of capital associated with the 'value of time passing' which can be measured by TFP growth, is that all technological progress is exogenous and it increases the possibilities of higher consumption in future (Pezzey et al., 2006, Pezzey, 2004). They further emphasize that the shifts in the terms of trade of natural resource exports should be a part of the value of time. Arrow et al. (2012) also included the value of technological progress as a component of a country's capital stocks. The case of including TFP growth in a comprehensive investment measure appears strong, mainly because of the established evidence that residual productivity plays a vital role in the growth of consumption for OECD countries (Ferreira & Vincent, 2005). However, there is limited evidence that the terms of trade favour the export of natural resources in the long-run (Blattman, Hwang, & Williamson, 2007), therefore, we limit the augmentation of GS for the value of TFP growth by using a measure of trend growth in TFP. An annual index of TFP is given by:

$$TFP = GDP \,/\, (Labour^{\alpha}\; Capital^{1-\alpha}) \qquad (7)$$

Where labour is the measure of hours worked, and capital is the stock of reproduced capital, and α is the elasticity of the output in relation to the labour. The resulting TFP index reinforces the interpretations of New Zealand economic growth. For instance, Fagerberg (2000) show that New Zealand achieved a total TFP growth of 51.3%, (1973 – 1990), with an average annual growth of 2.4%. Similarly, Färe, Grosskopf, & Margaritis (2001) studied relative TFP trends for Australia and New Zealand manufacturing sectors and concluded that New Zealand's TFP record in this sector has been slightly better on average than that of Australia.

Trend growth TFP estimates can be used to support the valuation of exogenous technological progress. Arrow et al. (2012) simply augmented their measure of comprehensive investment with the current value of TFP growth to show how technical progress increases the level of current income. Therefore, considering time as an uncontrolled capital stock means TFP's contribution to the change in wealth in any year should be included in our measure of GS. Our method to measure how TFP growth contributes to changes in the value of wealth follows Pezzey et al. (2006) and Hamilton &

Hartwick (2005b) where we use the annual index of TFP from (Greasley & Madsen, 2016) (equation 1) based on their preferred TFP (BDL) variant. Trend growth from these data for each year 1950-2015 was extracted using a Kalman Filter and used to construct a measure of the value of technological progress and to augment GS, Green and Super Green series over 10, 15, 20 and 30 years horizons. For sensitivity analysis, we used the present value of future changes in TFP of the aforementioned series with 1.4% per year and 2.8% per year discount rates to value technological progress, where the discount rates are matched with those for consumption and GDP per capita.

3.6 Consumption per capita and GDP per capita

Net present values for the future changes in ***real consumption per capita (C)***, ***real GDP per capita (GDP)*** and TFP data series as a proxy for technological change (***tp***) are estimated following Ferreira et al. (2008) over 10, 15, 20 and 30 years horizons with a 2.8% per year discount rates.[6]

3.7 Some comparisons of the measures

The increasingly comprehensive measures ***NNS, NNSR, NNSF, GS, NNSRtp, NNSFtp and GStp*** are illustrated in Figures 2 – 7, below. The values of all these measures, in real terms and as a percentage of GDP, were positive over the study period i.e. 1950 – 2015. Although there was a large decline in the measures in 1975 because of the lowest value of net exports in the period of 1950 – 1987, overall there was a steady upward trend for all data series in real-terms, except the NNSF series. This was mainly due to a sharp decline in the year-on-year changes in the forest volume. Year-on-year changes in forest volume peaked in 1996, as shown in Figure 4, followed by a sharp decline in following years, as land use switched to dairy farming and agriculture due to changes in profitability. This has subsequently resulted in the decline in the GS to GDP ratio since 1995 as shown in Figure 3.

[6] The long-run discount rate is derived from the mean nominal discount rate minus the rate of inflation, see appendix for sources. 2.8% is our benchmark discount rate, this rates sits just blow recent New Zealand Treasury discount rates projects over 10, 15, 20, and 30 years (3.06%, 3.38%, 3.57%, 3.87%). Spot rates from: http://www.treasury.govt.nz/publications/guidance/reporting/accounting/discountrates

Figure 2: Alternative measures of future well-being (real per capita)

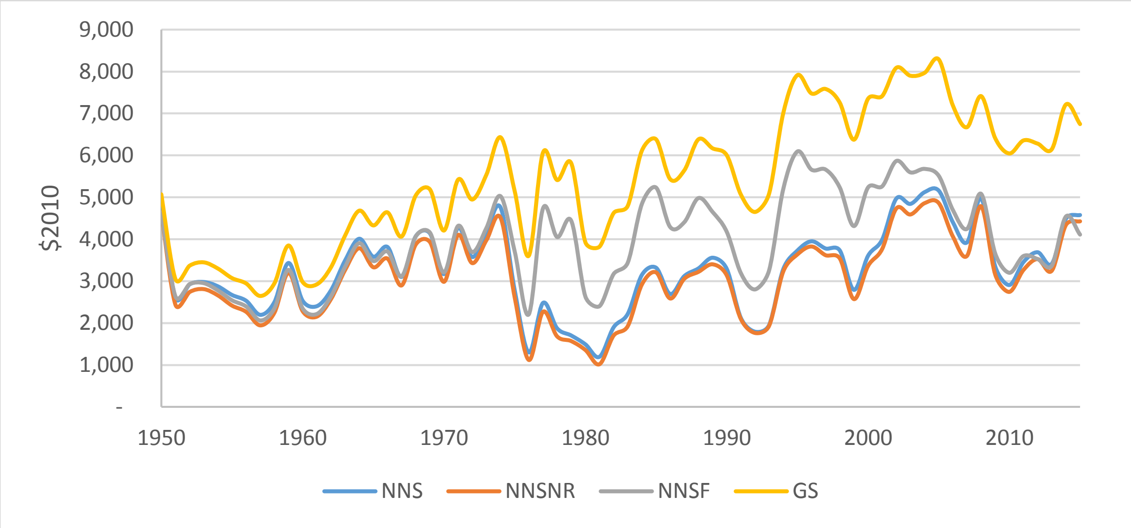


Figure 2: Alternative measures of future well-being as a percentage of GDP

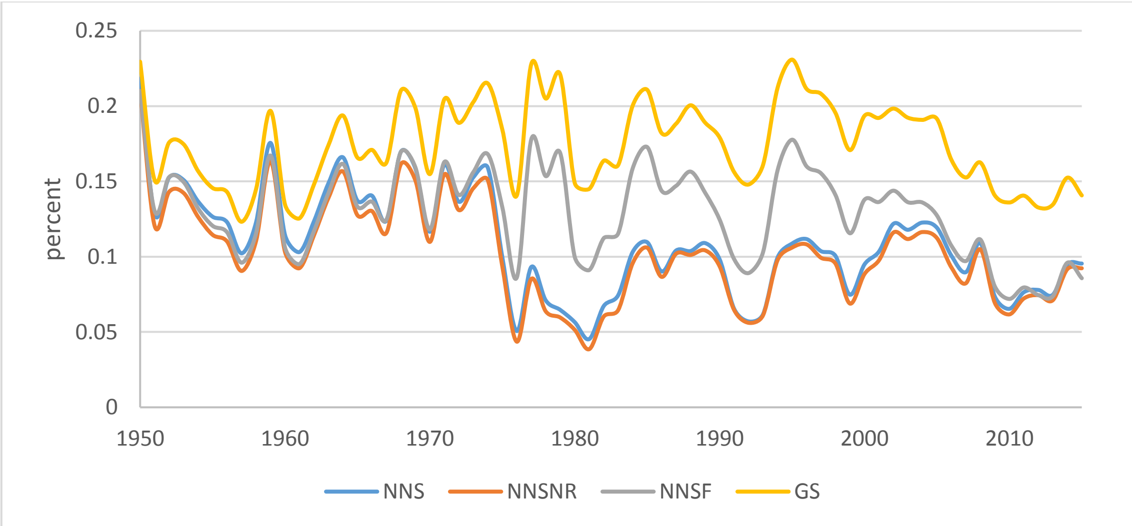


Figure 3: New Zealand forest volumes

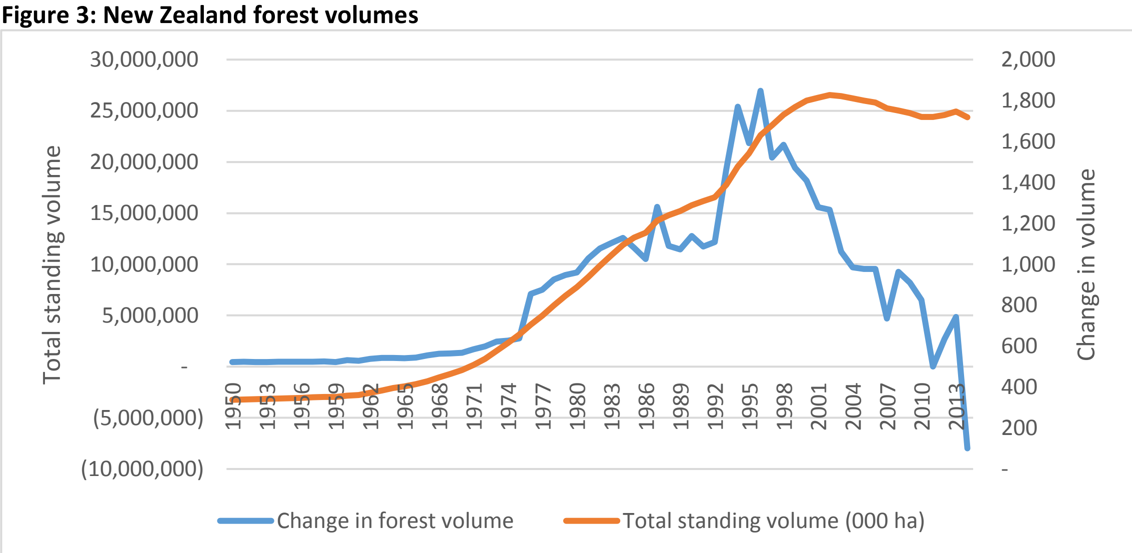


Figure 5a: PV of technological progress augmented NNSNR measure as a percentage of GDP at 2.8% discount rate over t=10, 15, 20, 30 year horizons

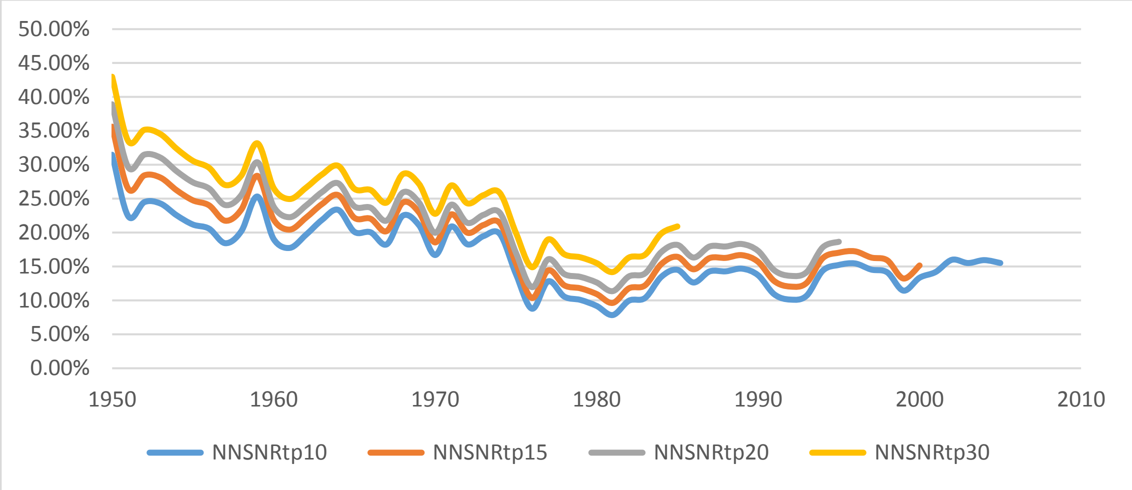


Figure 5b: PV of technological progress augmented NNSF measure as a percentage of GDP at 2.8% discount rate over t=10, 15, 20, 30 year horizons

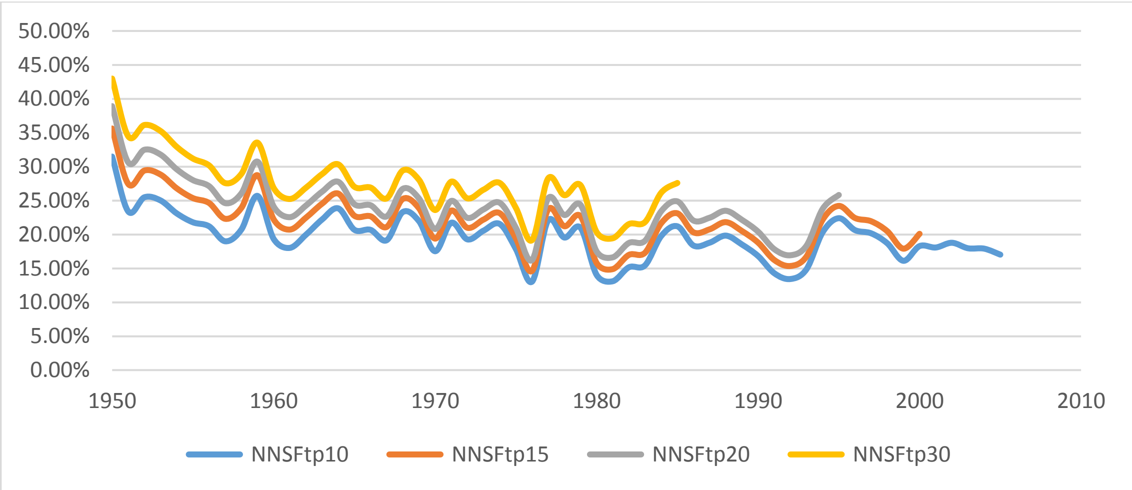


Figure 5c: PV of technological progress augmented GS measure as a percentage of GDP at 2.8% discount rate over t=10, 15, 20, 30 year horizons

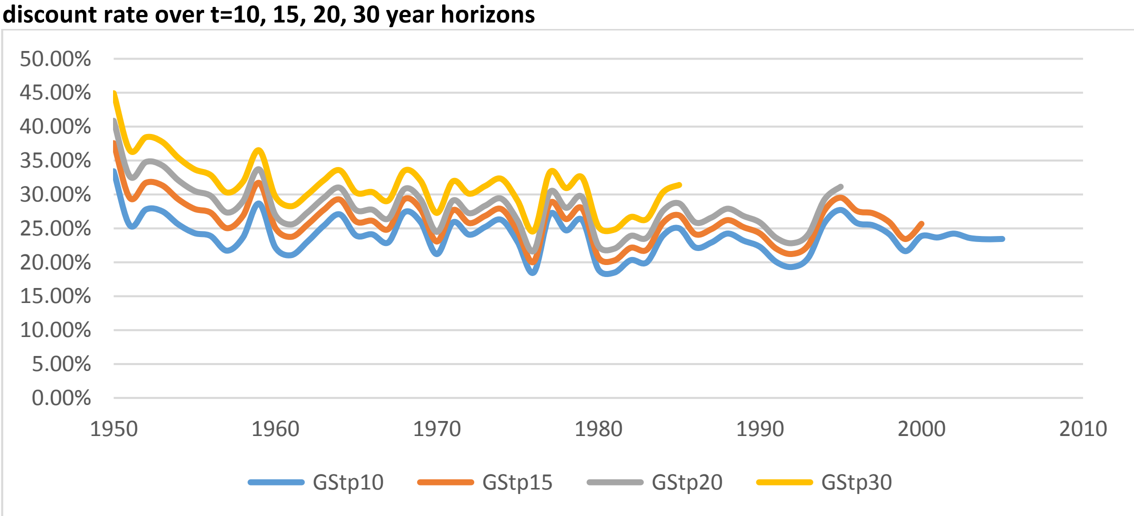


Figure 6: PV of future changes in real GDP over t=10, 15, 20, 30 year horizons with 2.8% discount rate

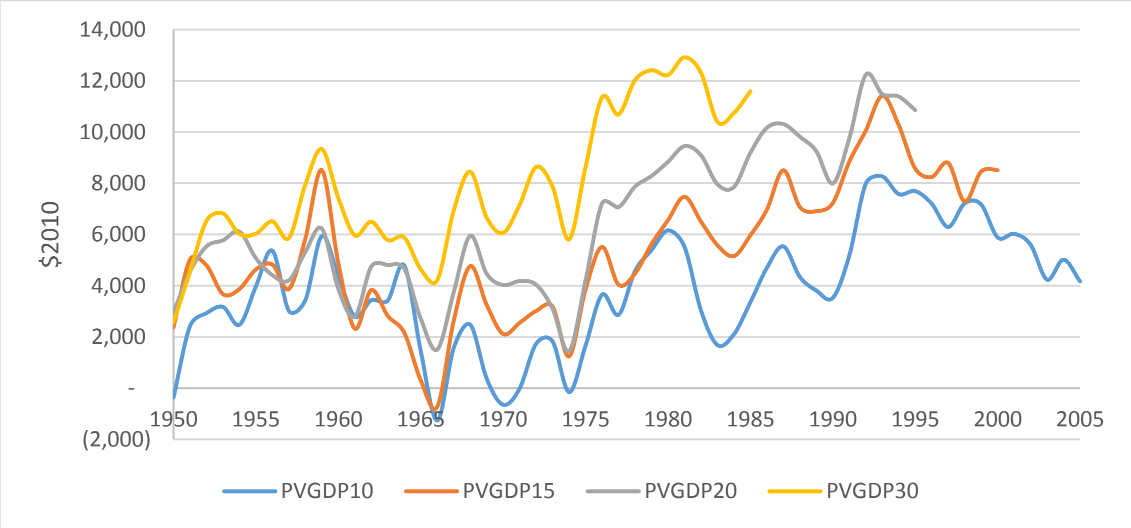
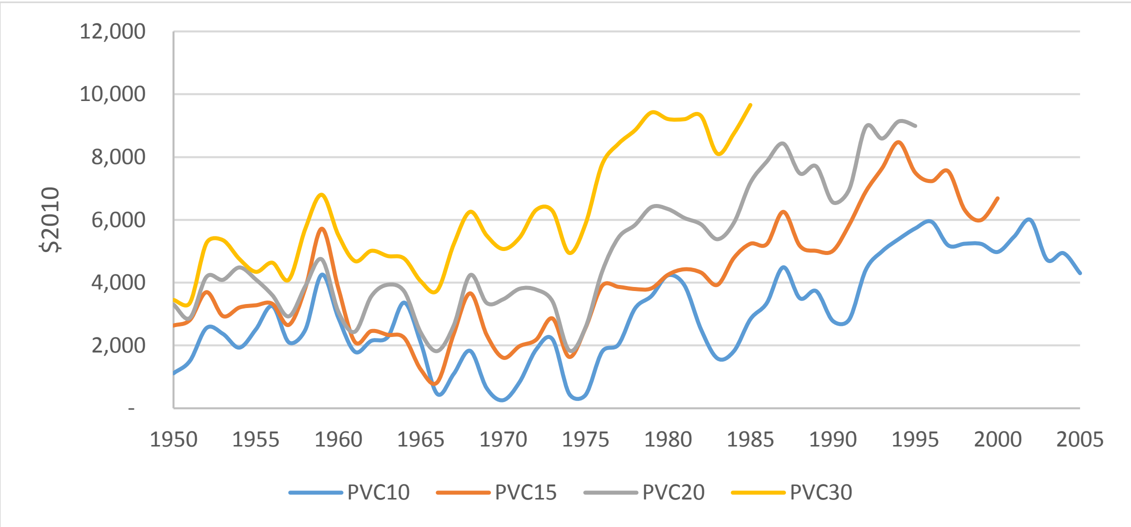


Figure 7: PV of future changes in real consumption over t=10, 15, 20, 30 year horizons with 2.8% discount rate



3.8 Varying population growth and wealth dilution

With varying population growth, FHV (2008) show that the relation between GS and the PV of future changes in consumption is altered by a ***wealth-dilution effect*** (equation 6). 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 GS 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 PV of an estimated stream of private and public consumption over 20 years. We discuss the effects of wealth-dilution on our estimates in Section 4 below.

3.9 Measuring well-being over time

We followed FHV (2008) who state that "economic theory predicts that the current change in national wealth, broadly defined to include natural and human capital as well as produced capital ("genuine savings"), determines whether the present value of future changes in consumption is positive or negative" in order to calculate the *net present values (NPVs) of future changes consumption per capita* and *future changes in GDP per capita in real terms* as measures of well-being. Both of these indicators align closely with the theoretical framework of GS. Data for these series are extracted from SNZ's Info share facility from 1972 to 2015, and the earlier data were sourced from NZOYBs. NPVs for these well-being measures are also calculated for four time horizons i.e. 10,15,20 and 30 years using a 2.8% discount rate. Trends in these data series are summarised in Figure 6.

4.0 Empirical results for testing the implications of a GS approach applied to New Zealand

This section provides a detailed discussion of the estimation methods and presents results of the various tests in relation to the GS model based upon the different measures of GS and well-being discussed above. Our empirical GS models are developed based upon two alternative measures of future well-being: ***real consumption per capita (C)*** and ***real GDP per capita (GDP),*** which are linked to increasingly comprehensive measures of savings, including technology augmented measures.

Using the theoretical framework, estimation and testing methods discussed earlier, let us first consider the relationship between the ***present value of real GDP per capita*** and ***NNS, NNSNR, NNSF*** *and* ***GS*** reported in Table 2.

Based upon equations (iii) and (iv) the following hypotheses are considered:

H_1: $\beta_0 = 0$ and $\beta_1 = 1$ jointly
H_2: $\beta_0 = 0$ and/or $\beta_1 = 1$ independently.

To avoid any confusion, there is no intention to claim that equations (iii) and (iv) are the 'best fitting' models to explain the LHS variable. The estimates (and their standard errors) are used within an equation that constitutes a test statistic and not a model, in much the same way as one would not regard the LHS of a Dickey-Fuller test to represent the best fitting explanation (model) of the LHS variable.

Estimates of β_1 fall in the range of -1.5 to 1.01. The proposition for β_1 supports the tests of GS as an indicator of future per capita income as discussed earlier. In the case of NNS and NNSNR, the hypothesis $\beta_1 = 1$ is rejected which means that the PV of future changes in real GDP per capita are lower than those indicated by the level of savings. Another interesting pattern that emerges is that the value of β_1 increases as we include more factors as we move from NNS towards the GS measure.

Table 2: Summary of results with the PV of the change in GDP per capita with a 2.8% discount rate over a 20 year horizon

1 Dependent	2 Independent	3 β_0	4 β_1	5 β_1=1 (χ^2)	6 β_0=0, β_1=1 (χ^2)
PVGDP	GNS	188.66	0.98***	0	0.04
PVGDP	NNS	10908.31***	-1.51***	33.28***	118.58***
PVGDP	NNSNR	10181.9***	-1.35***	26.82***	115.65***
PVGDP	NNSF	3674.04**	0.77*	0.3	47.73***
PVGDP	GS	1691.59	1.01***	0	20.57***
PVGDP	NNSNRtp	13399.47***	-1.29***	44.45***	52.5***
PVGDP	NNSFtp	4959.93*	0.24	2.89*	3.15
PVGDP	GStp	128.72	0.86**	0.14	4.94*

NOTES: Dependent variable is the present value of future GDP per capita in real terms over 20 years time horizon discounted at 2.8% discount rate. Independent are right-hand side variables. The technological progress (tp) series based on TFP are also discounted at 2.8% over 10, 15, 20 and 30 years time horizon.
For column 3, hypotheses H0: β0 = 0; H1: β0 ≠ 0 and for
column 4, H0: β1 = 0; H1: β1 ≠ 0 are tested using t-statistics where * denotes results are significantly different from zero at 10% level, ** at 5% and *** at 1%. For
column 5, hypothesis H0: β1 = 1; H1: β1 ≠ 1 and for
column 6, the joint hypothesis is H0: β0 = 0 & β1 = 1; H1: β0 ≠ 0 & β1 ≠ 1 are tested using a Wald Test which is distributed as **χ2** distribution with 1 (for column 5) or 2 degrees of freedom (for column 6) respectively.

For example, β_1 for the NNSNR, which counts mining as negative savings, is higher than that of NNS. Similarly, this value increases further when forestry is taken into the account in the NNSF. Thus GS, with a broader measure of natural capital, forestry and human capital has the highest value of its coefficient in Tables 2. Greasley et al. (2014b) and Greasley et al. (2016) have shown similar patterns in their results. Although the GS model is designed for infinite time horizons, in most of our results, we find the 20 years horizon for the two dependent variables, real GDP per capita and real consumption per capita, most relevant to New Zealand. This may be a function of the length of our time series – something we would hope to consider if we could construct longer time series. See the Appendix for a full set of results.

It seems that the estimates for NNS and NNSNR over a 20 years time horizon, with a 2.8% per year discount rates, have negative values. In the case of GS, the estimate of β_1 is 1.01, which, unsurprisingly is not different from 1.

The ***present value of future consumption per capita*** provides an alternative measure of well-being and it aligns somewhat better with theory (Greasley et al., 2014). The estimates of β_1 over the 20 years horizon show rising values of -0.71, 0.58, 0.87, 0.93 as the measure of savings becomes more comprehensive. It is noteworthy that only the GS measure in Table 3 also supports the stronger joint hypotheses, with non-rejection of **β_0=0, β_1=1.** We observe a somewhat similar pattern as in the case of ***real GDP per capita,*** suggesting in the work presented here that both GDP per capita and consumption per capita performed almost equally well as indicators of future well-being in the case of New Zealand.

Table 3: Summary of results with PV of change in consumption per capita (2.8% discount rate) 20 years horizon

1 **Dependent**	**2** **Independent**	**3** **β_0**	**4** **β_1**	**5** **β_1=1 (χ^2)**	**6** **β_0=0, β_1=1 (χ^2)**
PVC	GNS	-1015.26	0.94***	0.08	29.05***
PVC	NNS	7050***	-0.71**	25.19***	70.72***
PVC	NNSNR	6551.38***	-0.58	20.24***	72.43***
PVC	NNSF	1823.81	0.87***	0.21	22.63***
PVC	GS	560.44	0.93***	0.11	0.99
PVC	NNSNRtp	8442.9***	-0.65**	37.27***	39.54***
PVC	NNSFtp	1563.45	0.54*	2.08	20.11***
PVC	GStp	-1749.93	0.91***	0.12	76.89***

NOTES: See the notes from Table 2 for the explanation of null and alternative hypotheses and the levels of significance.

In their seminal study, FHV could not establish that GS had a significant and positive effect on the future consumption of OECD countries. Longer time horizons reiterate the importance of including technological progress in the measure of savings and wealth. A number of studies have emphasised how the omission of technological progress from the estimation of GS can provide misleading results, for example, see (Arrow et al., 2012, Pezzey et al., 2006, Pezzey, 2004, Weitzman, 1997). Following their suggestions, a number of empirical studies have included technological progress in their model of GS, for example, (Blum et al., 2017a, Blum et al 2017b, 2016, Greasley et al., 2014b, 2016, Hanley et al., 2016). Results of estimates of TFP growth series using alternative indicators for NNSNR, NNSF and GS series are also reported in Tables 2 and 3. It is worth noting that GS, by definition, includes the value of human capital as expenditure on education, which might be partially reflected in TFP; and using TFP for the NNSNR, NNSF and GS highlights the possibility of some double counting.

Technology augmented results exhibit the incremental pattern (increase) in the value of β_1 as the measure of savings become more comprehensive. There are nevertheless, situations where the value of β_1 itself is not significant. The values of β_1 estimates are close to 1 for the wellbeing measure *PVGDP* based upon the *GS* or *GStp* variants as shown in Table 2. These results make a strong case for the use of GS and its technology augmented version, in explaining the real GDP per capita measure (*PVGDP*). Turning to the PV of changes in consumption per capita *(PVC*), again the *GS and GStp* variants do not reject the null hypothesis **β_1=1**, and in the case of GS, **β_0=0, β_1=1.**

The *Appendix* as Tables A1, A2, and A3 present some additional statistics and results. One of the key patterns shown there is that, when the time horizons are matched for dependent and independent variables, β_1 exhibits lower levels of significance at 10 years time horizon which, increases or reaches a maximum level in most cases at 20 years horizon and declines again beyond that. This suggests (with these data) that the 20 years horizon is the most relevant for a New Zealand GS model given the extent of time-series data covering the period 1950 – 2015. This is not to say that a longer time series may find that such horizons are extended.

In summary, for two alternative measure of future well-being (*real GDP per capita and real consumption per capita)*, our results align closely with the theoretical relationship between GS and future well-being, and provide some initial support for the indicative capacity of the GS model, compared to previously published studies.

4.1 Genuine Saving and changes in future Wellbeing

The results presented so far suggest that New Zealand has been on a (weakly) sustainable development path over the period of consideration. Of equal interest is the theoretical literature, which ***relates GS to changes in wellbeing into the future***. For example, Arrow et. al., (2012) show that ***intergenerational wellbeing is rising over future periods if GS is positive when evaluated at the correct shadow prices in the current period***. Hamilton and Withagen (2007) show that, if genuine saving is positive and growing at a rate lower than the interest rate over an unbounded interval, then social welfare is everywhere increasing over this interval. Furthermore, FHV (2008) show that in any period t, the value of g (GS) is equal to the discounted value of changes in per capita consumption from t to infinity if the consumption rate ρ is adjusted downwards by the (constant) population growth rate. If population grows at a varying rate, then the relationship between GS and the PV of changes in future consumption is altered. From this FHV (2008) derive a reduced form relationship between GS and the PV of changes in future consumption (presented above as equations (5) and (6)).

The results presented so far effectively relate to whether GS is consistently positive from which we can then infer whether the economic data is consistent with weak sustainability. In the next section we will expand our estimation and testing to include the effects of wealth-dilution.

4.2 Wealth-dilution effects

FHV (2008) show that the relationship between GS (CI) and the PV of future changes in consumption is altered by a ***wealth-dilution effect*** (equation 6). 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, which identifies total wealth with the PV of an estimated stream of private and public consumption over a 20-year horizon.

A characteristic of New Zealand (and Australia) is that population has been growing much more rapidly than in Western Europe and the USA. From Greasley et al. (2017) for their period of interest (1946-2000) population grows, on average, at a rate of 1.75% in Australia; 0.33% in Britain; 0.63% in Germany and 1.28% in the USA. In the case of New Zealand; 1950-2015 saw population grow at an average rate of 1.38%. As a consequence, the possibility of a significant wealth-dilution effect (the spreading of capital among a larger population) may have particular resonance for New Zealand (and Australia).

The estimates of the non-technology and technology-augmented measures of GS (over a 20 year horizon) are presented as Table 4, below, and are based upon equation (6), which adjusts the savings-GDP and savings-consumption relationship for possible wealth-dilution. The form of the adjustment includes a wealth-related variable on both sides of the equation; hence, when we report the estimation results, we consider both OLS and 2SLS estimates, where the latter are used to counter any possible bias from endogeneity.

In terms of the actual results presented as Table 4, in all cases the point estimates of β_1 all exceed unity, however in three cases not significantly so. In terms of the alternative measures of wellbeing, 2SLS rejects $\beta_1=1$ when changes in real GDP per capita is used however, when consumption is the basis of the measure the hypothesis is not rejected for the non-technology augmented version of GS.

Table 4: Summary of results with the PV of the change in GDP per capita and PV of the change in Consumption, allowing for wealth-dilution with a 2.8% discount rate over a 20 year horizon.

Model	Dependent	Independent	β_0	β_1	$\beta_1=1$ (χ^2)	Weak instruments	Wu-Hausman
OLS	GDPWD	GStpWD	-569.94	1.47∗∗∗	4.64∗∗		
	GDPWD	GSWD	4222.78∗∗∗	1.28∗∗∗	2.25		
2SLS	GDPWD	GStpWD	-1587.69	1.69∗∗∗	8.44∗∗∗	58.27∗∗∗	7.07∗∗
	GDPWD	GSWD	3940.11∗∗∗	1.42∗∗∗	4.28∗∗	94.85∗∗∗	6.21∗∗
OLS	CWD	GStpWD	-1496.03∗	1.32∗∗∗	4.1∗∗		
	CPWD	GSWD	2841.54∗∗∗	1.13∗∗∗	0.85		
2SLS	CWD	GStpWD	-2001∗∗	1.43∗∗∗	6.34∗∗	61.52∗∗∗	3.44∗
	CWD	GSWD	2661.56∗∗∗	1.21∗∗∗	1.93	99.11∗∗∗	3.51∗

∗p<0.1; ∗∗p<0.05; ∗∗∗. WD refers to Wealth-Dilution; tp refers to technological progress augmented

With all point estimates of β_1 exceeding unity (typically but not exclusively, significantly) our wealth dilution adjusted estimates suggest that our broadest measure of GS (that includes technology augmentation) understates changes in wealth, at least in the context of understanding consumption changes over finite horizons of up to 20 years ahead.

There are, of course, other possibilities as to why the point estimates of β_1 in Table 4 all exceed unity. These include that the wealth dilution effects of population growth are overstated, or that the consumption discount rate is understated. Furthermore, much of the recent population growth since 1950 has been from immigration, and the extent to which migrants embody human capital not measured in the New Zealand national accounts, changes in its wealth might be understated in accounting for GS. The consumption discount rate embedded in the estimates may not correctly capture the degree of uncertainty surrounding the future and may understate the value of immediate consumption. Finally, the fact that the technology augmented results in the wealth dilution estimates exceed those without augmentation suggests that our measure of the effects of technological change (based upon TFP growth) are not capturing the actual contribution coming from technological change.

4.3 Savings-gaps

So far we have focused upon tests of (weak) sustainability and established that, even with wealth-dilution accounted for, New Zealand has been enjoying positive values for GS throughout the period. This in turn suggests that the results presented so far suggest that GS has been consistently positive over the period 1950-2015 from which we can infer that the data are consistent with weak sustainability.

However, as the World Bank (2011, p.41 &43) conclude that:

> ***"Even developed countries such as the United States and New Zealand have had positive ANS, but a decline in per capita wealth because saving has not been sufficient to compensate for population growth."***
>
> And for 2005 that,
>
> ***"The adjusted net saving gap measures, as a percentage of GNI, the difference between actual ANS and the amount necessary to maintain per capita wealth. The savings gap for the United States and New Zealand is 2 percent."***

It is to this issue that we now turn.

The results from which the above quotes relate, consider a snapshot for the year 2005. Based upon our measures, and taking an average of the equivalent of their ANS gap as a % of GNI, we confirm that (an average of the years 2004-2006) produces a gap of 2.11% for New Zealand (see, Table 5 below which also presents some averages over different periods).

Table 5: Measures of the Average GS Gap as a percentage of GNS

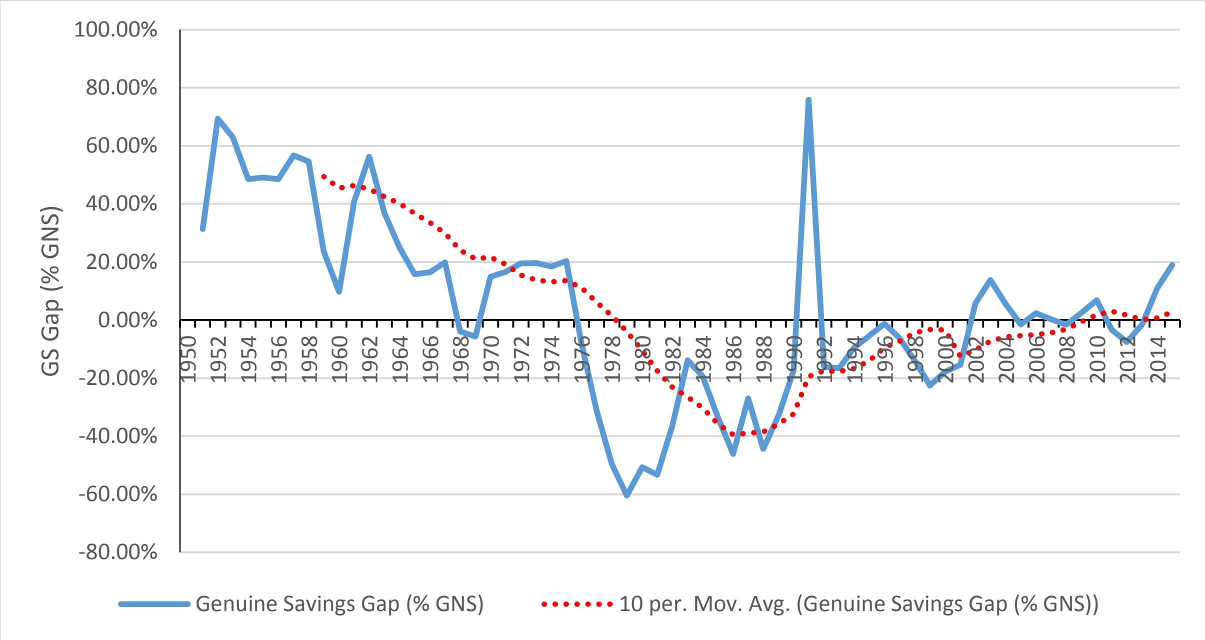
Period	Avg. GS Gap (% GNS)	Avg. GS Gap (% GNS) WB format
1955 - 2015	0.5%	0.5%
1970 - 2015	-9.0%	NA
1985 - 2015	-6.4%	NA
2000 - 2015	7.2%	7.2%
1955 - 1975	15.1%	15.1%
1975 - 1995	-22.7%	NA
1995 - 2015	-1.5%	NA
2004 - 2006	2.1%	2.1%

Positive (negative) number is bad (good) as it shows the country is saving less (more) than required to maintain sustainability. The World Bank (WB) has replaced negative numbers with NA (not applicable) in their estimates.

The results suggest that, over the period 1955-2015, New Zealanders should have saved an average of 0.5% more to maintain sustainability.

Looking at specific sub-periods, it is interesting to note that New Zealanders actions initially reflected (unsustainably) low savings rates, with the gap narrowing only to start to widen again recently. It is noteworthy that for 2000-2015 the average GS gap as a % of GNS is +7.2%, which is second only to 1955-1975 as a period of a large savings gap. This can perhaps be seen more readily via Figure 8 below.

Figure 8. Trends in the GS Gap as a percentage of GNS and its 10-year moving average



A positive (negative) number is bad (good) as it shows the country is saving less (more) than required to maintain sustainability. Source, Table 5 above.

Table 6: Savings year-on-year percentage changes in capital stocks.

Period	Human Capital	Fixed Capital	Non-renewable natural capital	Renewable natural capital
1950 - 2015	4.46%	3.49%	6.53%	5.71%
1960 - 2015	4.24%	3.43%	6.61%	7.87%
1970 - 2015	3.45%	2.99%	7.78%	7.87%
1980 - 2015	3.20%	2.39%	10.16%	7.87%
1990 - 2015	3.69%	2.82%	10.12%	7.87%
2000 - 2015	3.04%	2.53%	-0.01%	7.87%

4.4 Changes in wealth per capita

The second element of the World Bank (2010) p.41 &43, conclusion relates to:

> ***"New Zealand (has) had positive ANS, but a decline in per capita wealth because saving has not been sufficient to compensate for population growth."***

For 2005 the World Bank calculates that the changes in wealth per capita was (US$) -501. Using our new dataset and real NZ$ (discounted) we calculate the following:

Table 7: Average change in wealth per capita

Time horizon	Avg. Change in Wealth per capita (at 1.4% discount rate)	Avg. Change in Wealth per capita (at 2.8% discount rate)
1951 - 2015	-84.65	-57.90
1951 - 1975	-1624.22	-1344.29
1976 - 2000	1567.12	1304.49
2000 - 2015	-154.02	-86.14
2003 - 2007	-431.07	-295.09

Figure 9: Year-on-year change in wealth per capita (2.8% discount rate)

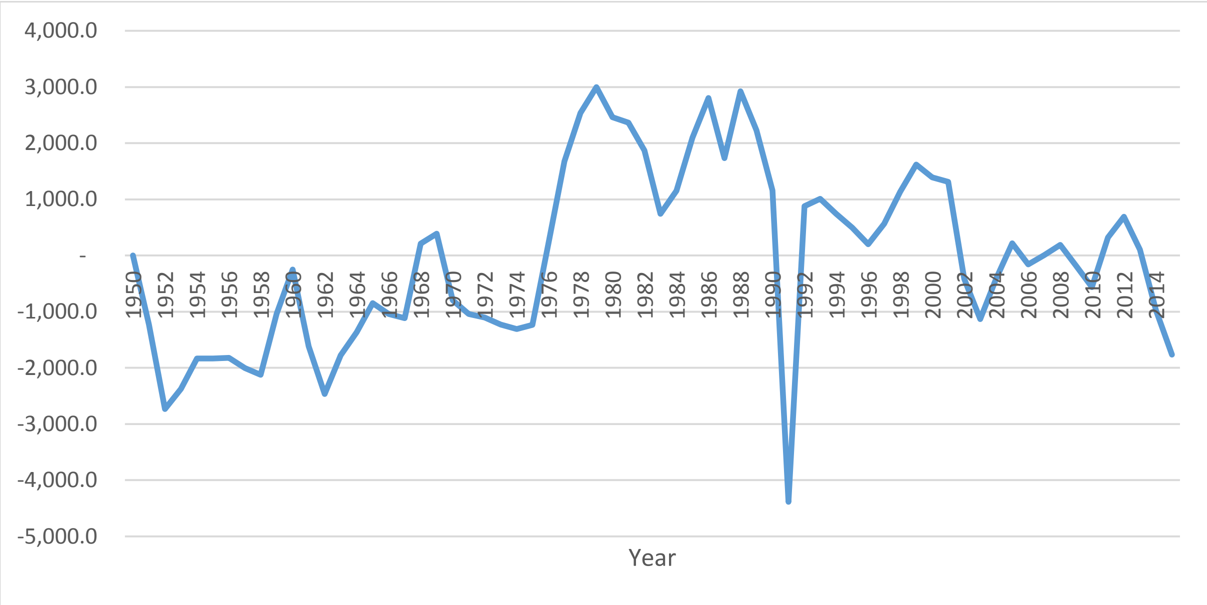
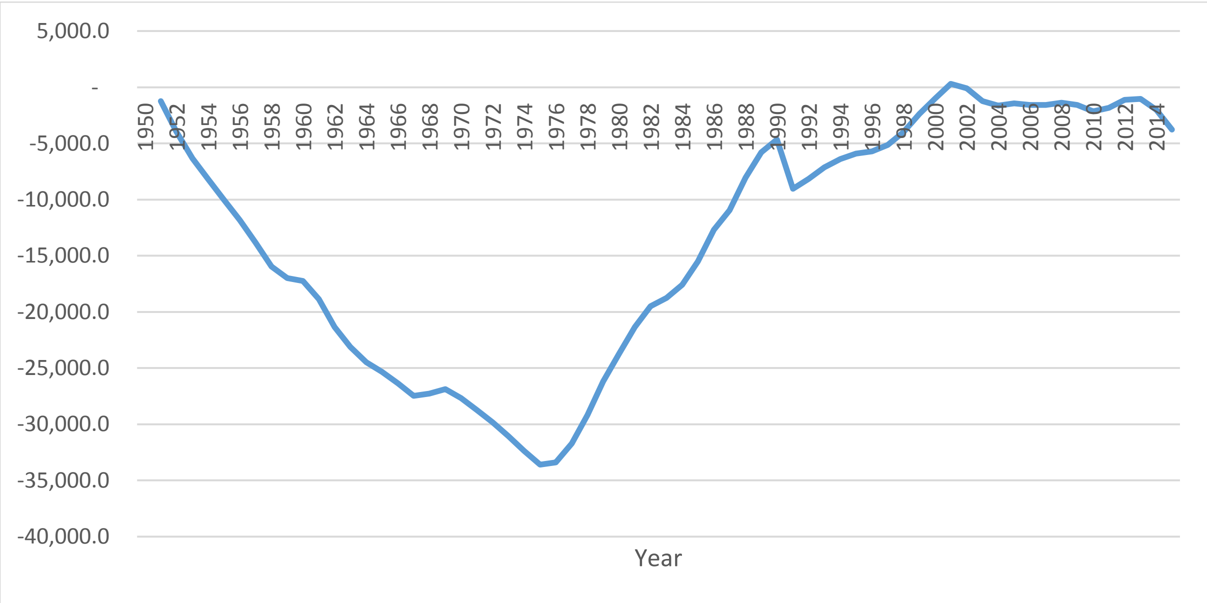


Figure 10: Cumulative change in wealth per capita



Compared with the point estimate for 2005 of (undiscounted) (US$) -501 our average for the period 2003-2007 ranges from (NZ$) -431 to -295 depending on discount rate. Given the different (expanded) dataset and the effect of discounting we see these two sources providing a similar pattern of declines in wealth per capita. Turning to the whole sample period, Figures 9 and 10 plot the time series of year-on-year changes in wealth per capita and the cumulative share in wealth per capita. Not surprisingly, the two figures reflect the savings-gap reported above, but present it in terms of real NZ$ per capita.

Although New Zealand remains weakly sustainable throughout the period, the effects of population growth have lead to wealth dilution with. At best, over the new millennium, New Zealand wealth per capita remains static.

4.5 Contributions from 'the Capitals'.

Table 6, above, presents a breakdown of the year-on-year percentage change contributions of the various forms of capital. It is interesting to note the steady decline of the contribution from **human capital**. This is of concern if we are correctly measuring the stock of human capital correctly (via expenditures on education). As noted previously, the extent to which 'brain-gain' by way of immigrant inflows of (NZ unfunded) human capital is not being captured could be an issue, but one might expect this to show-up in the measure of TFP. However, it is well understood (and our data reflect this) that in New Zealand TFP is consistently lower than in other OECD countries.

Contributions from **fixed capital** also show a declining trend – an issue also well documented in the case of New Zealand. For **non-renewable natural capital** there was an upward trend until the beginning of the new millennium where for the period 2000-2015 this form of capital appears to be adding nothing to the stock of capital. Combining the information from Tables 5 and 6 we get a finer-grained picture emerging. If we consider the 1970s- 1990s, the ***savings gap*** is around -8% (where negative is good). *This gap seems to have been mainly created via the contribution from non-renewable natural capital.* This is effectively reversed with a +7.2% savings gap, (positive is bad) for the period 2000-2015 when the contribution from non-renewable natural capital is -0.01 per cent.

The contribution from **renewable natural capital** has been effectively constant since the 1960s (at 7.87%).

Overall, therefore, Tables 5 and 6 present some 'good-news, bad-news' stories. On the good news, **renewable natural capital** (mainly forestry-related) provides consistently the largest contribution to the growth in the capitals. The bad news is that human capital and fixed capital taken together do not even match this contribution from renewable natural capital. On **non-renewable natural capital** it was singly the largest contributor to the total stock of capital for around 25 years from the mid-1970s to 2000. Although potentially bad news, in this case it was this type of capital that was contributing most to creating a negative savings gap (a good thing) which was reversed for the period 2000-2015 (where it stands at a large 7.2%) as its contribution declined to -0.1 % and the other capitals (especially human and fixed were unable to pick-up their own growth (in fact they declined in terms of their contributions). In order to reduce the large savings gap (the average GS gap as a percentage of GNS) that now exists, there need to be increasing contributions to total capital. If non-renewable natural capital is to be protected for e.g., environmental issues, then the other capitals (human, fixed and renewable natural) need to make significant additional contributions from what at the moment appears to be a **trend decline.**

5.0 Discussion

5.1 Summary

Genuine Savings has become one of the most popular, and perhaps important, indicators of sustainable development (Bank, 2011, Greasley et al., 2016). This indicator focuses on how well a country maintains its total asset base, i.e. *natural capital, human capital* and *produced capital,* over time considering how rents from the depletion of natural resources are utilized for current consumption or savings for the future. It permits discussion and testing of the effects of population growth, which potentially ***dilutes*** the amount of capital available to future generations. It also enables measures of ***savings gaps*** to be calculated with a view, perhaps to use government policy to close them for the benefit of future generations.

In this paper, we conducted tests of increasingly comprehensive measures of savings as indicators of long-term sustainability for New Zealand. The key contribution of this study has been to undertake the first medium/long-run test of the performance of Genuine Savings as an indicator of changes in future well-being in New Zealand. *We complied time series data on GS and other comprehensive savings measures, over the period 1950 – 2015 for New Zealand and tested how well they explain changes in future well-being over time.*

Key contributions of this study are as follows: Firstly, the estimates of New Zealand Genuine Savings have been constructed for an extended period over 1950 – 2015 and then tested as to how well they explain changes in future well-being over time. Secondly, these measures of savings have also been extended to augment the value of exogenous technological progress. For two alternative measure of future well-being (*real GDP per capita* and *real consumption per capita*), our results align closely with the theoretical relationship between GS and future well-being, and provide strong support for the indicative capacity of the GS model, compared to previously published studies. Thirdly, changes in future well-being measures have been measured over different time horizons (10,15,20 and 30[7] years).

Given the length of data series, we found the empirical relationship between well-being measures and comprehensive savings exhibits non-linear patterns relative to the future time horizons used to calculate discounted values for example, this relationship is insignificant at 10 year time horizons; it becomes significant or increasingly significant for 20 years and then insigniciant thereafter. *These results reinforce the need to advance technologically to attain higher productivity so that the impact to technology becomes significantly visible in the shorter time spans.*

New Zealand's GS as reported here has been positive since the start of our data series even without allowing for a value of technological advancement[8]. The average GS to GDP ratio as reported here has been around 17%, which is sufficient to meet the generalized "Hartwick" rule over time suggested by Hamilton & Hartwick (2005b). However, New Zealand's *real consumption per capita* has been growing at a much lower rate of about 1.5% for the same

[7] See Appendix for detailed results

[8] However, as the World Bank (2011), p43, concludes: "Even developed countries such as the United States and New Zealand have had positive ANS but a decline in per capita wealth because saving has not been sufficient to compensate for population growth."

period. This suggests New Zealand has maintained higher levels of genuine savings[9] compared to those of for example, Australia, which has an average growth rate of saving of 5% with a similar growth rate in consumption (Greasley et al., 2016)[10].

We have also calculated i) the effects of wealth-dilution (e.g. of a growing population having less capital available to them) and ii) an average GS gap as a percentage of GNS and iii) the contributions to total capital wealth arising from the four capitals (human, fixed, non-renewable natural and renewable natural capital).

Although over the period of study, New Zealand has consistently satisfied the criteria for weak sustainability (with GS throughout being positive), there are periods (including all of this millennium) where a ***savings gap*** exists with ***wealth dilution*** also putting some strain of sustainable development.

The key discussion here around the utility of GS as an indicator of weak sustainability raises the possibility that the non-renewable natural resource depletion is understated in empirical estimates. For example, Brown, Asafu-Adjaye, Draca, & Straton (2005) have shown that coral and water resources degradation may not be reflected in the estimates. Although we included the rents from the mining of all natural resources available from national statistical office in our estimates, historical data constructed here may not include all changes in natural capital. Without allowing a value of technological advances, measures of comprehensive savings slightly understate the PV value of future well-being measures, and including technology augmented measures of savings explain changes very closely.

5.2 Some potential government policy-related issues to consider

5.2.1 Issues

The results from the paper suggest that over the period 1950-2015, New Zealand:

- Has exhibited positive GS from which we can infer that the economic data is consistent with being on a *weakly sustainable development path*

[9] The World Bank (2011), p41., concludes that: "The adjusted net saving gap measures, as a percentage of GNI, the difference between actual ANS and the amount necessary to maintain per capita wealth. The savings gap for the United States and New Zealand is 2 percent."

[10] "For example, a detailed analysis of human capital accounts for Canada, New Zealand, Norway, Sweden, and the United States unambiguously shows that human capital is a leading source of economic growth." World Bank (2011), p105. This conclusion, however, is based upon the exclusion of all forestry related measures of capital from the World Bank estimates.

- Has experienced an average GS to GDP ratio of approximately 17%, which is sufficient to meet the generalized "Hartwick" rule over time suggested by Hamilton & Hartwick (2005b).
- Has a rate of technological progress (as measured by TFP), which has contributed less to explaining measures of future wellbeing than in similar developed economics for example, Australia, Germany, Britain and the USA.
- Has experienced savings gaps (where positive is bad and negative good), which have varied over the period, with the decade 2000-2010 exhibiting a +7.2% average GS gap as a percentage of GNS.
- Exhibits a situation where wealth dilution effects are important and will put further strain on sustainable development if population growth rates continue at comparatively high levels, unless the stock of capitals increases at a rate faster than experienced in the past 65 years[11].
- Has experienced year-on-year increases in human, fixed and renewable natural capital assets that are internationally comparatively low (and typically declining) leaving, until very recently, non-renewable natural capital growth rates to reduce the savings gap. Moving into a period where non-renewable natural capital growth rates are now stagnant (or declining), will put the onus on the other capitals to grow at historically unprecedented levels in order to seek to achieve future positive changes in wealth per capita.
- In terms of wealth per capita, wealth dilution has been the typical pattern to emerge from the beginning of the sample through to the early 1990s, created, in the main, by a persistent GS/NNS savings gap. This gap is beginning to re-emerge in the new millennium, where for the period 2000-2010 it was (on average) +7.2%. This is reflected in changes in wealth per capita of between $ -431 and $ -295.

5.2.2 Policy

- Although the data suggest that the necessary conditions for weak sustainability and the Hartwick Rule are being satisfied in New Zealand, there are issues of concern in terms of long term sustainable development in particular:

[11] This assumes we are measuring brain-gain human capital from migration sufficiently accurately.

- Changes in per capita wealth have been declining due to the effects of savings gaps and wealth-dilution
- Savings gaps have re-emerged in New Zealand (they were more persistent and higher in the early parts of the sample than in the new millennium) in part because of:
    - Relatively small effects from technological change when applied to the stocks of capital in relation to maintaining and/or increasing future wellbeing
    - Low and downward trending additions to stocks of human[12] and fixed capital; stagnant growth rates in the stocks of renewable natural capital.
    - Non-renewable natural capital was the area with the highest growth rates, which in part was reversing the savings gaps in the 1980s, and '90s. However, this reversed in the new millennium leading to a 7.2% savings gap. The challenge here is to increase the growth rates of the other capitals (particularly human) to compensate for the decline in the growth of non-renewable natural capital exploitation, which is likely to encounter longer-term environmental resistance.
- Including forestry (standing timber) in measures of GS leads to positive increases in future wellbeing and likely positive changes in per capita wealth.
    - More land dedicated to forestry will increase the stock of renewable natural capital with positive carbon sink effects, but there may be tensions regarding optimal harvesting rates. Furthermore, the opportunity cost to increasing forest area by planting native forest (which cannot be harvested by law) would likely be significant and may might impact on the future growth of other capitals, for example, produced capital.
    - The shift to more dairy farms using marginal lands puts pressures on the expansion of forestry.

[12] For example, a detailed analysis of human capital accounts for Canada, New Zealand, Norway, Sweden, and the United States unambiguously shows that human capital is a leading source of economic growth." World Bank (2011), p105

- The net contributions to future wellbeing and wealth per capita arising from valuing water effects have yet to be fully evaluated.
- The net contributions to future wellbeing and wealth per capita arising from fishery related effects have yet to be fully evaluated, although the WB is confident the rents from fisheries in New Zealand are likely to be 'substantial'[13].
- If/when the effects of emissions (other than CO_2) are monetised, conclusions relating to sustainable development paths may need to be revised. To some extent, the substitution forestry for other agricultural land may mitigate some of these (likely to be unambiguously negative) effects. However, this is likely to have short-term effects on GDP per capita and consumption per capita growth rates.

5.3 Some caveats and potentially fruitful areas for further research

This is only the second[14], formal, piece of research applying GS-type approaches to New Zealand data. In this paper we extend the sample period and include the contribution made by forestry to renewable natural capital.

However, the work in this area remains 'in progress'. Below we identify some of the important caveats to consider when reading both the detailed results and also e.g., policy-related implications.

1. We have made some progress, compared to the WB, by including the value of forests (standing timber) in New Zealand and by extending the sample period, which is crucially important for GS-type approaches. Forests make little or no contribution to natural capital in the countries considered by Greasley *et. al.,* (2017), but are significant in the case of New Zealand. In our results here, the inclusion of renewable natural capital (like forests) is important when calculating GS (without augmentation by TFP) where its contribution is relatively large in New Zealand.

[13] "There are notable exceptions to this, such as fisheries in Iceland, New Zealand, and Namibia, where better management allows substantial rents to be generated" World Bank (2011), p.21
[14] World Bank (2011)

2. Although we have included an estimate of the value of standing timber, we have not sought to calculate the positive effects forests have such as carbon sinking, soil stabilization, water purification, climate regulation etc. This would no doubt increase the value of forestry (and other similar types of renewable natural capital) within this framework.
3. We have not calculated the effects of shifting land-use patterns, e.g., the reduction in land used for forestry as dairy farming moves into more marginal land.
4. We have not calculated the costs associated with GHG emissions, which other authors have sought to include in their GS models. Although there are good models (and international prices) for CO_2, which may be a positive (net) contribution for New Zealand, the same is not the case for other emissions e.g., methane. Such work would be important future work.
5. The economic value of fisheries has not been included. Work by the WB suggests that fisheries in New Zealand are likely to be positive[15]. Further work in this area would be an important future development of this programme of research[16].
6. Similarly, the contributions and costs of water-related natural capital have not been included.
7. Health related costs (again something some authors have tried to quantify in their GS-related work) have not been calculated or included in this paper.
8. Potential *non-marketed values* of natural capital (or social or cultural capital) have not been calculated.
9. Technological progress has proven to be an important element in terms of trying to explain the roles various forms of capital have on future wellbeing. Total final productivity is often the 'go-to' measure of progress, although it is not without its critics. In this paper we use the TFP estimates from Greasley and Madsen (2016) and the extent to which they are a 'good' measure for New Zealand is something we have not considered. It certainly seems that technological progress seems to contribute less to our GS estimates than in other countries where the GS approach has been

[15] "There are notable exceptions to this, such as fisheries in Iceland, New Zealand, and Namibia, where better management allows substantial rents to be generated" World Bank (2011), p.21.

[16] "New Zealand introduced a system of individually tradable quotas to manage its fisheries, resulting in a large competitive market for fish quota sales and rentals. This system has established a direct market price for the asset value of fisheries, which is used in the New Zealand fisheries accounts. "World Bank (2011) p. 135.

implemented (see Greasley et. al. 2016), however, this conclusion does not seem to be out of line with other commentary on New Zealand's (low) productivity performance over the period.

10. Human capital is an important element in the GS-sustainability story. Ultimately, all other forms of capital are finite and it is this element, which perhaps holds the key to sustainable development at least cost to the other capitals. Here we measure human capital via its expenditure cost. This is a relatively crude (though not uncommon) way to measure the growth in human capital and other options are available (see Le et al. (2003). However, to date these alternative (better) measures have not been extensively applied to New Zealand data and would be another area where fruitful futures research could be undertaken. This may lead to a more positive prognosis for the contributions human capital has (and could have) on the growth of total wealth.
11. Overall, therefore, it is hard to speculate what the net effect of including and resolving caveats 2-10 would be for calculations of for example, GS, savings gaps, wealth dilution and ultimately long-term sustainability in the case of New Zealand. In this paper we have provided a detailed framework of i) the GS approach; ii) the data demands and iii) some preliminary results. Future work should be able to build on these foundations to get a clearer and more detailed picture to inform for example, policy advice and actions to identify, and potentially steer or nudge the economy to *sustainable development paths*.

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Appendix

Table 2A: Comparison of the World Bank and New Zealand national statistics office data sources

Variable	World Bank Definition	World Bank Data Sources	Stat NZ Definition	Data Source
Population	**Series Code: SP.POP.TOTL** The total population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship--except for refugees not permanently settled in the country of asylum, who are generally considered part of the population of their country of origin. The values shown are midyear estimates.	(1) United Nations Population Division. World Population Prospects, (2) United Nations Statistical Division. Population and Vital Statistics Report (various years), (3) Census reports and other statistical publications from national statistical offices, (4) Eurostat: Demographic Statistics, (5) Secretariat of the Pacific Community: Statistics and Demography Programme, and (6) U.S. Census Bureau: International Database.	Population (Est.) Mean for year ended 31 December	The New Zealand Official Yearbooks and Stat NZ InfoShare
GDP (nominal)	**Series Code: NY.GDP.MKTP.CN** GDP at purchaser's prices is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in current local currency.	World Bank national accounts data, and OECD National Accounts data files.	Gross Domestic Product - expenditure measure Nominal actual aggregates (Annual-March) in NZD	The New Zealand Official Yearbooks and Stat NZ InfoShare
GDP (real)	**Series Code: NY.GDP.MKTP.KN** GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in constant local currency.	World Bank national accounts data, and OECD National Accounts data files.	Price deflator gross domestic product - (National currency: 2010 = 100) - New Zealand estimated from Retail Price Index and Consumer Price Index	The New Zealand Official Yearbooks and Stat NZ InfoShare
Education Expenditure	**Series Code: NY.ADJ.AEDU.CD** Education expenditure refers to the current operating expenditures in education, including wages and salaries and excluding capital investments in buildings and equipment.	World Bank staff estimates using data from the United Nations Statistics Division's Statistical Yearbook, and the UNESCO Institute for Statistics online database.	Government expenditure on education Actual aggregates (Annual-March) in NZD	The New Zealand Official Yearbooks and Stat NZ InfoShare
Forestry	NO DATA FROM WB			
Energy and Minerals	**Series Code: NY.ADJ.DNGY.CD** Energy depletion is the ratio of the value of the stock of energy resources to the remaining reserve lifetime (capped at 25 years). It covers coal, crude oil, and natural gas. **Series Code: NY.ADJ.DMIN.CD** Mineral depletion is the ratio of the value of the stock of mineral resources to the remaining reserve lifetime (capped at 25 years). It covers tin, gold, lead, zinc, iron, copper, nickel, silver, bauxite, and phosphate.	World Bank staff estimates based on sources and methods in World Bank's "The Changing Wealth of Nations: Measuring Sustainable Development in the New Millennium" (2011).	Nominal aggregate value from the production of metals, minerals and energy less production cost in NZD	The New Zealand Official Yearbooks and Stats published by New Zealand Petroleum and Minerals (Ministry of Business, Innovation and Employment)
Net National Savings (NNS)	**Series Code: NY.ADJ.NNAT.CD** Net national savings are equal to gross national savings less the value of consumption of fixed capital.	World Bank staff estimates based on sources and methods in World Bank's "The Changing Wealth of Nations: Measuring Sustainable Development in the New Millennium" (2011).	NNS = GNS – Consumption of fixed capital	
Gross National Savings (GNS)	**Series Code: NY.ADJ.ICTR.GN.ZS** Gross savings are the difference between gross national income and public and private consumption, plus net current transfers.	World Bank national accounts data files.	Gross national savings are calculated as Gross Fixed Capital Formation + Change in inventory (Annual-March) in NZD	The New Zealand Official Yearbooks and Stat NZ InfoShare
Consumption of fixed capital	**Series Code: NY.ADJ.DKAP.CD** Consumption of fixed capital represents the replacement value of capital used up in the process of production.	World Bank staff estimates using data from the United Nations Statistics Division's National Accounts Statistics.	Consumption of Fixed Capital (Annual-March) in NZD	The New Zealand Official Yearbooks and Stat NZ InfoShare

In addition to the data series mentioned in the above table, detailed description on the compilation of the other data series is as follows:

Consumption, GDP and GDP deflator:
Total public and private consumption in real per capita terms is calculated as a residual from GDP. Similarly, all other data series to conduct hypothesis testing are constructed in real per capita terms.
Data source: The New Zealand Official Yearbooks, NZOYBs hereafter, (1950 – 1971) and Stats NZ (1972 – 2015).

Population:
Estimated mean population of New Zealand for year ended 31 December.
Data source: NZOYBs (1950 – 1971) and Stats NZ (1972 – 2015).

Education expenditure:
Human capital is used as a proxy of human capital. This is given by the Total government expenditure on education (including primary, secondary, tertiary etc.) and salaries excluding capital expenditure.
Data source: NZOYBs (1950 – 1971) and Stats NZ (1972 – 2015).

Discount rates:
We derived discount rates from the mean of bonds long-term series from Homer & Sylla (2005). We subtracted the percentage of GDP deflator from the bond percentage to get the real discount factor, which is 1.4% per year. We also use an alternative discount rate of 2.8% for sensitivity analysis.

Gross national savings (GNS):
GNS is calculated by subtracting public and private consumption from gross national income plus net exports.
Data source: NZOYBs (1950 – 1971) and Stats NZ (1972 – 2015).

Depreciation of fixed capital:
It is the replacement value of capital used in the process of production and consumption. Pre-calculated data series for depreciation of fixed capital are given Stats NZ.

Net national savings (NNS):
It is the difference between GNS and depreciation of fixed capita.

Rents from natural capital (excluding forestry):
Rents from the mining of natural resources are given by:

$$Rents = production\ volume\ \times\ unit\ resource\ rent$$

$$Unit\ resource\ rent = unit\ price - cost\ of\ production$$

$$Cost\ of\ production = labour\ emplpyed\ \times\ average\ salaries$$

In our dataset, the market value of all mineral resources is obtained from NZOYBs (1950 – 1993), and from the Mining Production Statistics annual publications by the Ministry of Business Innovation and Employment (2000 – 2015). Missing data between these periods is imputed from linear extrapolations.

Data for total labour employed in the mining sector and average annual wage in the mining industry are also compiled from NZOYBs and Stats NZ.

NNSNR:
This is the difference between NNS – Rents from natural capital (excluding forestry)

Rents from forestry:

Rents from change in forestry are calculated as:

$$Rents =\ Change\ in\ standing\ forest\ volume\ \times\ unit\ price - cost\ of\ production$$

$$Standing\ forest\ volume \\ =\ Standing\ stock\ of\ forest\ \times\ average\ volume\ per\ hectare$$

$$Cost\ of\ production =\ labour\ employed\ \times\ average\ salaries$$

Forest volumes include the standing volume of both natural and planted forest in hectares. Standing volume in cubic meters is estimated by multiplying the standing stock of forest (in hectares) by average volume per hectare provided by the New Zealand Ministry of Primary Industries in the National Exotic Forest Description (NEFD) and Forest Owners Association (FOA) facts and figures reports. The cost of production is estimated from the product of a number of people employed in the forestry industry and real wage. Finally, market prices are determined by the average export price of all forest products from New Zealand.
Data source: Labour and wages data from NZOYBs Stats NZ, estimated round wood removals from New Zealand forests from Ministry of Primary Industries, forest volume and volume per hectare from NFED and FOA.

NNSF:
It is given by the sum of Green Series and Rents from forestry.

Genuine Savings (GS):
Finally, GS is obtained from the sum of Super green series and investments human capital (i.e. education expenditures).

Total Factor Productivity (TFP):

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 1950-2015 is extracted using a Kalman Filter and used to construct a measure of the value of technological progress. TFP series are compiled for GS, Green and Super Green series over 10, 15, 20 and 30 years horizons. For sensitivity analysis, we used the present value of future changes in TFP of aforementioned series with 1.4% per year and 2.8% per year discount rates to value technological progress, where the discount rates are matched with those for consumption and GDP per capita.

Net present values of consumption per capita, GDP per capita

Net present values for the future changes in real consumption per capita, real GDP per capita and TFP data series are estimated following Ferreira et al. (2008) over 10, 15, 20 and 30 years horizons with a 2.8% per year discount rate.

Table A1: Summary statistics of key variables

Statistic	N	Mean	St. Dev.	Min	Max
PVGDP10	56	3,857.81	2,309.92	−1,258.79	8,268.49
PVGDP15	51	5,366.83	2,679.47	−724.12	11,418.59
PVGDP20	46	6,446.64	2,867.35	1,445.68	12,234.16
PVGDP30	36	7,930.82	2,710.34	2,577.62	12,919.38
PVC10	56	3,025.72	1,596.44	258.23	5,994.27
PVC15	51	4,107.84	1,881.91	827.29	8,472.81
PVC20	46	4,950.11	2,085.52	1,821.60	9,134.51
PVC30	36	6,111.22	1,914.30	3,361.28	9,656.93
NNSNRtp10	56	4,577.83	1,125.61	2,069.16	6,955.17
NNSNRtp15	51	4,992.47	1,059.53	2,540.64	7,870.10
NNSNRtp20	46	5,390.89	1,095.28	2,998.45	8,598.33
NNSNRtp30	36	6,121.04	1,185.19	3,739.74	9,496.08
NNSFtp10	56	5,520.64	1,140.67	3,343.64	7,678.24
NNSFtp15	51	5,927.73	1,049.77	3,748.86	8,298.27
NNSFtp20	46	6,228.14	962.17	4,158.92	8,851.96
NNSFtp 30	36	6,774.67	911.06	4,911.85	9,496.08
GStp10	56	6,812.08	1,556.70	4,661.02	10,142.70
GStp15	51	7,115.40	1,321.39	5,145.97	10,120.95
GStp20	46	7,328.77	1,112.55	5,556.03	10,674.65
GStp30y	36	7,727.93	958.64	6,308.96	9,925.12

Table A2: Summary of results with PV of change in GDP per capita at 2.8% discount rate

1 Dependent	2 Independent	3 β_0	4 β_1	5 β_1=1 (χ^2)	6 β_0=0, β_1=1 (χ^2)
PVGDP10	GNS	1159.91	0.39**	12.42***	121.36***
PVGDP15	GNS	266.69	0.77***	0.77	13.54***
PVGDP20	GNS	188.66	0.98***	0	0.04
PVGDP30	GNS	5033.94*	0.48	1.38	19.51***
PVGDP10	NNS	5490.67***	-0.51	23.57***	28.68***
PVGDP15	NNS	8406.79***	-1.01**	23.04***	66.32***
PVGDP20	NNS	10908.31***	-1.51***	33.28***	118.58***

PVGDP30	NNS	13310.59***	-1.81***	51.87***	243.57***
PVGDP10	NNSNR	5240.37***	-0.46	20.95***	29.12***
PVGDP15	NNSNR	7834.33***	-0.87**	19.02***	67.6***
PVGDP20	NNSNR	10181.9***	-1.35***	26.82***	115.65***
PVGDP30	NNSNR	12832.36***	-1.78***	48.55***	250.26***
PVGDP10	NNSF	2170.64*	0.43	4.51**	4.56
PVGDP15	NNSF	3060.06**	0.61*	1.23	20.22***
PVGDP20	NNSF	3674.04**	0.77*	0.3	47.73***
PVGDP30	NNSF	6691.32***	0.36	1.54	100.13***
PVGDP10	GS	1347.24	0.48**	7.86***	29.34***
PVGDP15	GS	1569.45	0.77***	0.89	2.32
PVGDP20	GS	1691.59	1.01***	0	20.57***
PVGDP30	GS	4390.24**	0.81**	0.23	68.17***
PVGDP10	NNSNRtp10	5744.58***	-0.41	26.65***	32.21***
PVGDP15	NNSNRtp10	9342.73***	-0.9**	28.77***	36.07***
PVGDP20	NNSNRtp10	12934.35***	-1.5***	50.32***	84.87***
PVGDP30	NNSNRtp10	16483.22***	-1.96***	143.93***	316.67***
PVGDP10	NNSNRtp15	7027.27***	-0.66**	29.15***	44.16***
PVGDP15	NNSNRtp15	9253.38***	-0.78**	26.77***	27.85***
PVGDP20	NNSNRtp15	13250.89***	-1.39***	48.51***	66.18***
PVGDP30	NNSNRtp15	17486.25***	-1.94***	178.12***	318***
PVGDP10	NNSNRtp20	8207.62***	-0.89***	44.8***	86.49***
PVGDP15	NNSNRtp20	10330.04***	-0.98***	35.84***	36.74***
PVGDP20	NNSNRtp20	13399.47***	-1.29***	44.45***	52.5***
PVGDP30	NNSNRtp20	18265.3***	-1.91***	185.02***	286.84***
PVGDP10	NNSNRtp30	8426.9***	-0.93***	75.51***	245.47***
PVGDP15	NNSNRtp30	9866.81***	-0.95***	74.46***	134.91***
PVGDP20	NNSNRtp30	13209.82***	-1.28***	104.23***	112.52***
PVGDP30	NNSNRtp30	19416.1***	-1.88***	164.61***	212.33***
PVGDP10	NNSFtp10	1859.23	0.36	5.54**	34.97***
PVGDP15	NNSFtp10	3301.37	0.39	2.76*	2.76
PVGDP20	NNSFtp10	5406.33**	0.2	2.87*	11.85***
PVGDP30	NNSFtp10	12404.27***	-0.89	12.38***	55.99***
PVGDP10	NNSFtp15	1984.31	0.3	4.79**	47.54***
PVGDP15	NNSFtp15	2888.19	0.42	2.62	4.87*
PVGDP20	NNSFtp15	5390.66*	0.18	3.11*	5.78*
PVGDP30	NNSFtp15	14336.73***	-1.15**	17.41***	47.3***
PVGDP10	NNSFtp20	4838.48**	-0.23	12.05***	81.7***
PVGDP15	NNSFtp20	5173.75*	-0.02	6.12**	15.11***
PVGDP20	NNSFtp20	4959.93*	0.24	2.89*	3.15
PVGDP30	NNSFtp20	14896.67***	-1.15**	18.8***	38.18***
PVGDP10	NNSFtp30	9806.05***	-1.04***	44.22***	258.08***
PVGDP15	NNSFtp30	9709.12***	-0.83**	30.41***	112.45***
PVGDP20	NNSFtp30	9450.98***	-0.6	16.52***	32.27***
PVGDP30	NNSFtp30	14586.47***	-0.98**	16.95***	24.09***
PVGDP10	GStp10	647.09	0.47**	7.62***	107.65***
PVGDP15	GStp10	650.61	0.72**	1.04	11.75***
PVGDP20	GStp10	1167.29	0.84**	0.18	0.37
PVGDP30	GStp10	7337.48**	0.1	3.19*	21.46***
PVGDP10	GStp15	-99.7	0.54**	3.5*	113.56***
PVGDP15	GStp15	63.41	0.75***	0.89	25.5***

PVGDP20	GStp15	641.06	0.85**	0.16	1.16
PVGDP30	GStp15	8891.73**	-0.15	4.83**	14.01***
PVGDP10	GStp20	2358.25	0.14	7.78***	142.08***
PVGDP15	GStp20	1315.7	0.51	1.98	37.32***
PVGDP20	GStp20	128.72	0.86**	0.14	4.94*
PVGDP30	GStp20	9415.51**	-0.21	5.54**	9.6***
PVGDP10	GStp30	10325.09***	-0.98***	45.76***	370.4***
PVGDP15	GStp30	9176.58***	-0.66**	26.2***	168.37***
PVGDP20	GStp30	6904.46**	-0.2	9.65***	51.47***
PVGDP30	GStp30	8895.02**	-0.12	5.39**	5.59*

NOTES: See the notes of Table 2 (main text) for the explanation of null and alternative hypotheses and the levels of significance.

Table A3: Summary of results with PV of change in consumption per capita at 2.8% discount rate

1 Dependent	2 Independent	3 B0	4 B1	5 B1=1 (X^2)	6 B0=0, B1=1
PVC10	GNS	-604.2	0.52***	21.36***	513.75***
PVC15	GNS	-1036.77	0.78***	1.81	130.71***
PVC20	GNS	-1015.26	0.94***	0.08	29.05***
PVC30	GNS	2549.31	0.59*	1.85	1.95
PVC10	NNS	2513.28***	0.16	14.53***	14.99***
PVC15	NNS	5060.12***	-0.32	18.29***	35.68***
PVC20	NNS	7050***	-0.71**	25.19***	70.72***
PVC30	NNS	9277.66***	-1.07***	47.03***	176.22***
PVC10	NNSNR	2429.98***	0.2	12.82***	12.86***
PVC15	NNSNR	4720.45***	-0.22	15.17***	38.44***
PVC20	NNSNR	6551.38***	-0.58	20.24***	72.43***
PVC30	NNSNR	8972.72***	-1.04***	44.21***	187.52***
PVC10	NNSF	390.07	0.67***	3.9**	26.72***
PVC15	NNSF	1087.59	0.8***	0.77	2.86
PVC20	NNSF	1823.81	0.87***	0.21	22.63***
PVC30	NNSF	4148.65***	0.57	1.47	76.41***
PVC10	GS	26.67	0.57***	14.71***	170.09***
PVC15	GS	265.61	0.78***	2.11	17.39***
PVC20	GS	560.44	0.93***	0.11	0.99
PVC30	GS	2659.05**	0.79***	0.63	37.37***
PVC10	NNSNRtp10	2422.8***	0.13	20.42***	72.84***
PVC15	NNSNRtp10	5542.57***	-0.33	25.8***	27.08***
PVC20	NNSNRtp10	8309.76***	-0.78***	39.97***	44.61***
PVC30	NNSNRtp10	11512***	-1.24***	120.18***	180.67***
PVC10	NNSNRtp15	3593.8***	-0.15	32.19***	135.45***
PVC15	NNSNRtp15	5412.61***	-0.26	25.26***	36.55***
PVC20	NNSNRtp15	8444.71***	-0.71**	39.79***	39.81***
PVC30	NNSNRtp15	12176.61***	-1.23***	143.1***	173.12***
PVC10	NNSNRtp20	4364.52***	-0.34*	57.2***	277.1***
PVC15	NNSNRtp20	6261.8***	-0.45*	39.94***	79.73***
PVC20	NNSNRtp20	8442.9***	-0.65**	37.27***	39.54***

PVC30	NNSNRtp20	12643.48***	-1.21***	145.39***	156.31***
PVC10	NNSNRtp30	4596.72***	-0.41***	106.6***	740.38***
PVC15	NNSNRtp30	5945.6***	-0.46***	108.08***	440.3***
PVC20	NNSNRtp30	8085.82***	-0.65***	105.28***	222.2***
PVC30	NNSNRtp30	13278.44***	-1.17***	129.46***	129.46***
PVC10	NNSFtp10	-619.44	0.66***	4.09**	176.82***
PVC15	NNSFtp10	378.08	0.7***	1.54	26.57***
PVC20	NNSFtp10	2160.01	0.54	1.9	2.42
PVC30	NNSFtp10	7430.23***	-0.26	10.37***	21.89***
PVC10	NNSFtp15	-181.58	0.51**	6.5**	244.9***
PVC15	NNSFtp15	-63.28	0.7***	1.58	56.84***
PVC20	NNSFtp15	1941.32	0.52	2.11	9.1**
PVC30	NNSFtp15	8596.66***	-0.44	14.36***	17.05***
PVC10	NNSFtp20	1652.35	0.14	16.9***	361.42***
PVC15	NNSFtp20	1507.92	0.37	5.54**	95.22***
PVC20	NNSFtp20	1563.45	0.54*	2.08	20.11***
PVC30	NNSFtp20	8866.13***	-0.45	15.57***	15.6***
PVC10	NNSFtp30	4846.26***	-0.4**	56.65***	830.46***
PVC15	NNSFtp30	4514.23***	-0.2	33.98***	419.71***
PVC20	NNSFtp30	4712.43**	-0.09	18.38***	156.4***
PVC30	NNSFtp30	8459.86***	-0.35	14.36***	18.68***
PVC10	GStp10	-1062.18	0.6***	12.49***	482.82***
PVC15	GStp10	-1102.37	0.8***	1.41	121.19***
PVC20	GStp10	-671.58	0.9***	0.17	23.32***
PVC30	GStp10	3841.94*	0.38	3.13*	3.32
PVC10	GStp15	-1186.07	0.56***	9.32***	535.77***
PVC15	GStp15	-1675.65	0.81***	1.26	190.57***
PVC20	GStp15	-1300.42	0.91***	0.12	48.42***
PVC30	GStp15	4562.95*	0.24	4.33**	6.13**
PVC10	GStp20	398.15	0.29	16.2***	628.4***
PVC15	GStp20	-931.99	0.65***	2.68	222.82***
PVC20	GStp20	-1749.93	0.91***	0.12	76.89***
PVC30	GStp20	4737.37*	0.2	4.91**	12.68***
PVC10	GStp30	5143.18***	-0.39**	62.11***	1192.26***
PVC15	GStp30	4027.62**	-0.12	31.73***	634.45***
PVC20	GStp30	3073.86	0.13	12.93***	267.29***
PVC30	GStp30	4291.55	0.24	5.05**	30.35***

NOTES: See the notes of table 2 notes for the explanation of null and alternative hypotheses and the levels of significance.