Sustaining intergenerational well-being

A thesis

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by

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Abstract

This PhD thesis comprises two published papers and four working papers (which are already in the process of publication) on multi-dimensional, interrelated and complex subjects of sustainability and well-being. The thesis covers the history of sustainability and well-being as independent subjects and discusses their evolution into a unified subject matter, sustainability and well-being (SaW). We combined big data methods for discourse analysis with traditional literature review methods to compile an enormous amount of literature to summarise work previously done in this field. Moreover, we analysed 125 years of text data from New Zealand parliamentary debates and policy documents to demonstrate the semantic evolution of SaW in New Zealand.

Whilst conceptually sustainability and well-being are interrelated, since well-being is the ultimate goal of all development endeavours and inter-generational sustainability is the constraint, most of the classic economic models have viewed them independently. Prior approaches have led to the development of rather incomplete and to some extent inappropriate policy guiding tools such as GDP. In contrast, contemporary well-being-oriented frameworks in economics have included components of both well-being and sustainability. However, they often take extreme and somewhat differently motivated positions in defining the scope of sustainability and differ significantly in allowing the operating space for development to deliver human well-being. This results in two conflicting notions of sustainability: i) strong sustainability and ii) weak sustainability. In this thesis, we have critically analysed both of these groups and have suggested a balanced and where appropriate nested approach, rather than either of these extreme positions.

We have adopted a common measure of inter-generational weak sustainability Genuine Savings (GS) to conduct the empirical case study for long-term sustainability in New Zealand. It transpires that New Zealand is weakly sustainable, however, the increase in total wealth has not always matched population growth resulting in an intermittently occurring savings gap. Furthermore, we have empirically shown the predictive power of GS to predict changes in future subjective well-being in a global context over different time horizons.

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"We do not inherit the Earth from our ancestors;

we borrow it from our children."

– Native American Proverb

Thesis related research outcomes

The following research items has been produced from this thesis.:

Peer reviewed publications

Qasim, M. (2017). Sustainability and Wellbeing: A scientometric and bibliometric review of the literature. *Journal of Economic Surveys*, 31(4), 1035–1061. Wiley Online Library.

Qasim, M., Oxley, L. & McLaughlin, E. (2018). Genuine savings as a test of New Zealand weak sustainability. *Environment, Development and Sustainability*. doi:10.1007/s10668-018-0185-0

Invited to 'revise and resubmit' after first review

Qasim, M. & Grimes, A. (2018). Sustainability and wellbeing: The dynamic relationship between subjective wellbeing and adjusted net savings. *Ecological Economics.*

Working papers and book chapter

Qasim, M. (2018). Sustainability and wellbeing: a text analysis of New Zealand parliamentary debates, official year books, and ministerial documents. Working Papers in Economics, University of Waikato.

Qasim, M. (2018). Some Links between Sustainability and Well-Being. Working Papers in Economics, University of Waikato. Retrieved from https://ideas.repec.org/p/wai/econwp/18-13.html

Qasim, M. & Grimes, A. (2018). Sustainable economic policy and well-being: The relationship between adjusted net savings and subjective well-being. Motu Working Paper, Motu Economic and Public Policy Research.

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Conference papers and posters

Qasim, M., & Oxley, L. (2015). "What Came First – Wellbeing or Sustainability?" A Systematic Analysis of The Multi-Dimensional Literature Using Advanced Topic Modelling Methods. 15th International Conference of the International Society for Scientometrics and Informetrics.

Qasim, M., Oxley, L. (2016). The Scientometrics of Sustainability and Well-being. Western Economic Association International 12th International Conference. Singapore.

Qasim, M., Oxley, L. & McLaughlin, E. (2018). Testing Genuine Savings as a Long-Run Sustainability and Well-Being Indicator of New Zealand. Western Economic Association International 93rd Annual Conference. Vancouver, Canada.

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Chapter 1: Introduction

One of the main aim of economics is to seek to enhance well-being of people over time. It seems widely believed that this is achievable only through continuous economic growth. Empirical evidence nevertheless has suggested that ever-rising economic output can do more harm than good as a larger population puts unprecedented burdens on the planet. Waste, emissions and exploitation of natural resources to produce goods and services in order to enable economic growth intensifies the concern of doing irreversible damages to life-supporting ecosystem services of the planet. Consequently, enhancing well-being turns into a sustainability challenge. In this chapter, we elaborate the sustainability challenge from several aspects which will provide the structure for the remaining chapters in the thesis.

One can ask, where does the obsession with economic growth as the only way to develop come from? The emphasis on gross domestic product (GDP)[1], is illustrated by W.W. Rostow in his work *"The Stages of Economic Growth: A Non-Communist Manifesto."* (Rostow, 1956). According to him, development is a process of economies passing through five stages of economic growth: i) living in a traditional society in which a nation's output is restrained by its state of technology; ii) pre-conditions of take-off with the beginning of institutional and industrial development; iii) the 'take-off' stage where growth becomes a normal condition; iv) driving to maturity, where countries specialise in the industries of their choice regardless of their natural resource base; v) and the most important stage relevant to this is high mass consumption stage where people can buy the consumer goods of their choice. Even now, more than half a century later, the richest economies in the world view GDP growth as the preferred solution to their economic problems.

We are financial, politically and socially, committed to economic growth. Our current financial systems are designed to achieve the highest monetary returns putting continuous pressure on organizations to achieve high profits to repay debts

[1] GDP is the total value of goods and services produced in an economy in a year. GDP, soon after its invention in 1930s, became a key goal of policymakers.

with interest to the investors. Politically, slower GDP growth rates are viewed as losing their place among emerging economic powerhouses. One of the key aims of governments seems to be to raise tax revenue without actually increasing taxes, and continuous GDP growth has been a promising way to achieve this. This political philosophy has not changed much over the last half of the century. For instance, J.F. Kennedy, ran for election with a promise to deliver 5% growth in the 1960s, and presently, Donald Trump has a goal to deliver 3% GDP growth in 2018.

Socially, on the one hand, people seem obsessed with getting ahead of their peers in terms of having more or consuming more, in order to live the kind of lives of they value or *"have a reason to value"*[2]; on the other hand, some want to do the planet a favour by becoming vegans, eating meat of ethically raised beef, driving modern emission-free electric vehicles or buying the latest technology with minimal footprint over its lifetime. Vibrant media provides people *"reason to value"* things in the age of consumerism whose philosophy is grounded in Sigmund Freud's lucrative retail therapy according to which purchasing transforms into happiness, for details see Freud (2003). So, no matter, whether you want to buy a luxury item or adopt austerity, there is a new product for you every coming year which is superior to its predecessors (Raworth, 2017).

We appear to focus on growth perhaps because we grew up to see that growth is good. We would like to see our children grow, our gardens, crops, and economies to grow. In nature itself, growth is a healthy stage. Many economies in the world e.g. Nepal, Bangladesh are at this stage, which according to the World Bank, grew over 7% in 2017.[3] However, there is a limit to growth in nature, from the height of humans to the spread of deserts, oceans and forests, nothing grows indefinitely. Rather things grow, and they mature after a certain stage so that they can thrive over the long-run. Similarly, economic growth is subject to limits after a certain stage (i.e. noted as steady state in economy (Daly, 1977, Fenichel & Abbott, 2014, Sessa & Ricci, 2014); and going forward, Raworth (2017) has suggested that

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[2] See Amartya Sen's capability approach which describes functional capabilities of peoples enabling their freedom to lead the kind of life they value (Sen, 1999).
[3] Figures downloaded from the World Bank databank website: https://data.worldbank.org/ accessed on 11th November 2018.

we need economies which can thrive whether they grow or not (like a flourishing tree after passing the growth stage).

None of the above-mentioned foci on growth are insuperable, but they deserve a great deal of attention from a wide range of stakeholders going forward. A journey of growth driven policies has taken the nominal GDP of the world from 1.37 trillion in 1960 to 80.68 trillion in 2017[4]; and, without doubt, this has resulted in the prosperity of billions of people. However, recently the global economy is becoming increasingly divisive with the immense share of returns to capital accruing to a small fraction of the world's richest (Raworth, 2017). We, therefore, need financial, political and social innovations to overcome structural dependencies on growth so that we can thrive by maintaining a balance between social, economic and ecological boundaries.

1.1 Rise of sustainable well-being

Historically sustainability and well-being (SaW) have evolved as independent subjects. The term "well-being" originally finds its roots in medical, psychological, anthropometric and happiness studies (Qasim, 2017, 2018). Well-being in economics has been broadly understood as enabling individuals to satisfy more of their personal preferences through higher levels of real income per capita. Any policies aiming to enhance preference satisfaction of the masses without rendering anyone with reduced choices can increase well-being effectively (Hicks, 1946). However, others argue that higher growth, or increases in income do not necessarily enhance the well-being of people (Easterlin, 1974, Stevenson & Wolfers, 2008, Tella & MacCulloch, 2008). Higher growth can be achieved without creating new jobs or paying decent salaries to people (Dalziel, Saunders, & Saunders, 2018). Raworth (2017) argues further, higher economic growth may or may not increase well-being, but it certainly increases environmental footprints in the production processes and contributes to destabilization of the ecosystem services.

[4] World GDP figures (in current US$) has been taken from World Bank databank website: https://data.worldbank.org/ accessed on 11th November 2018.

As the fear that economies are becoming more degenerative by destabilizing the delicately balanced life-supporting ecosystem services (clean air, drinkable water, breathable air) of the earth, the debate over whether we should feed people or save the planet has already begun (FAO, 2018, Rolston, 1996)? The logical answer is, we have to do both. The subsequent question is how much everyone in the world can have without causing any irreversible damages by going past planetary boundaries? Anthropocentric developing countries are interested in meeting the basic needs of their people whereas, the developed countries are rich enough to think about the environment. With such competing priorities of the nations, it is somewhat artificial to isolate the simple trade-offs between hungry people and conserving the planet. This debate has eventually led from growth-oriented economic models to the economics of sustainable well-being.

We need a range of indicators, or perhaps a dashboard of indicators, to integrate multi-dimensional well-being as an objective function of all economic activities under a sustainability constraint (Defra, 2009, Kulig, Kolfoort, & Hoekstra, 2010, Neumayer, 2007, Qasim, 2017, 2017, Ramos & Caeiro, 2010, Raworth, 2017, Rinne, Lyytimäki, & Kautto, 2013, 2013, Stiglitz et al., 2010). This is already reflected by recent SaW frameworks. For example, at the international level, the OECD's *Better Life Index* encompasses 11 indicators under three pillars of SaW: quality of life, material standards of living, and environmental sustainability (OECD, 2011). Similarly, the United Nation's set of 17 Sustainable Development Goals (SDGs) adopted by its member states in 2015 provides a shared plan for intergenerational peace and prosperity for people and the planet (UN, 2015). The World Bank's World Development Indicators (WDI) database provides more than 1300 indicators for over 214 countries and more than 30 group of countries dating back, in some cases, 50 years (World Bank, 2016).

Equally, governments around the world are also adopting a range of indicators for policy making and evaluating the progress on how their economies are thriving beyond mere economic growth. For instance, the government of New Zealand has adopted the Treasury's Living Standard Framework (LSF) in 2017 (Treasury, 2018) for policy decision and analysis. The Australian Treasury published a similar well-being framework in 2004 (Treasury, 2004). After a rigorous public consultation on what matters to people, the UK launched a program for measuring national well-being in 2010 (ONS, 2010). Italy, Spain, the Netherlands, and many other countries have also been pursuing alternative ways to evaluate progress in relation to well-being (EPRS, 2014). So, it is clear that countries are interested to bring well-being in addition to growth in their policy frameworks.

1.2 Research question and objectives

Although human well-being has been gaining the attention of policymakers as the ultimate goal of the state, it is still observed that well-being of some citizens is sacrificed by policies aiming to boost GDP growth. GDP growth alone typically ignores social aspects of well-being on a broader canvas and is often inconsistent with planetary limits to growth and waste assimilation generated in the production, transportation, consumption, and disposal processes (Dalziel, Saunders, & Saunders, 2018). Consequently, this thesis aims to bind inter-related SaW from several dimensions and analyses genuine savings, as a comprehensive indicator of inter-generational sustainability, and as a predictor of future well-being.

Key research questions of this PhD thesis are:

- What is sustainability and well-being in economics?
- How are sustainability and well-being inter-related?
- What is the best way to measure sustainable well-being comprehensively?

The specific aims of the research are to:

- Consider, via an extensive literature reviews, the history of sustainability and well-being as independent subjects and explain the emergence of sustainable well-being in economics.
- Identify the seminal works and networks of scholars working on SaW research and explain inter-linkages between them.
- Explore semantic relationships between sustainability and well-being to better understand the subject from a very large text corpus.
- Offer realistic and comprehensive ways to measure sustainability and well-being.
- Offer policy recommendations to support individual contributions aiming to sustain well-being over the long-run.

1.3 Rationale for a PhD by Publication

During a traditional PhD by thesis, although the author may present work at conferences, journal articles from the research are generally published after the submission. In my case, when I presented my work on SaW using modern bibliometric analysis and topic modelling methods to TPM[5], ISSI[6] and WEAI[7] conferences, I felt an urgency to make a meaningful contribution to help fellow researchers struggling to narrow down an enormous amount of literature. Furthermore, there was a need to expedite the academic community's acceptance and approval for the argument of adopting Genuine Savings as a measure of weak sustainability as a better indicator of intergenerational sustainability and well-being. This could be best achieved by publishing as part of progress through the PhD journey rather than doing so after its conclusion. The approach has also led to the chance to work closely with New Zealand Treasury to contribute genuine savings and weak sustainability aspects to their LSF and strategies for the future.

This PhD involves four distinctive areas of my academic interest and professional experiences in these fields. Each of them lies within mainstream disciplines: i) intergenerational sustainability; ii) objective and subjective well-being; iii) economic literature and history; iv) and big data in social sciences. Thus, publications as a part of PhD make it easier to communicate the work and to engage with a diverse academic audience and get feedback promptly. Peer-reviewed publications included in this thesis have undergone an intensive review process by the independent academic scholars who are acknowledged experts in their field. Similarly, working papers have been published after intensive internal review and feedback from national and international conferences.

Based on the published work as part of this PhD thesis, one of the main contributions of this research, Genuine Savings as an indicator of long-term sustainability, is already accepted in the academic world of sustainability thereby achieving its goal of addressing the urgency of making an impact and adding to the

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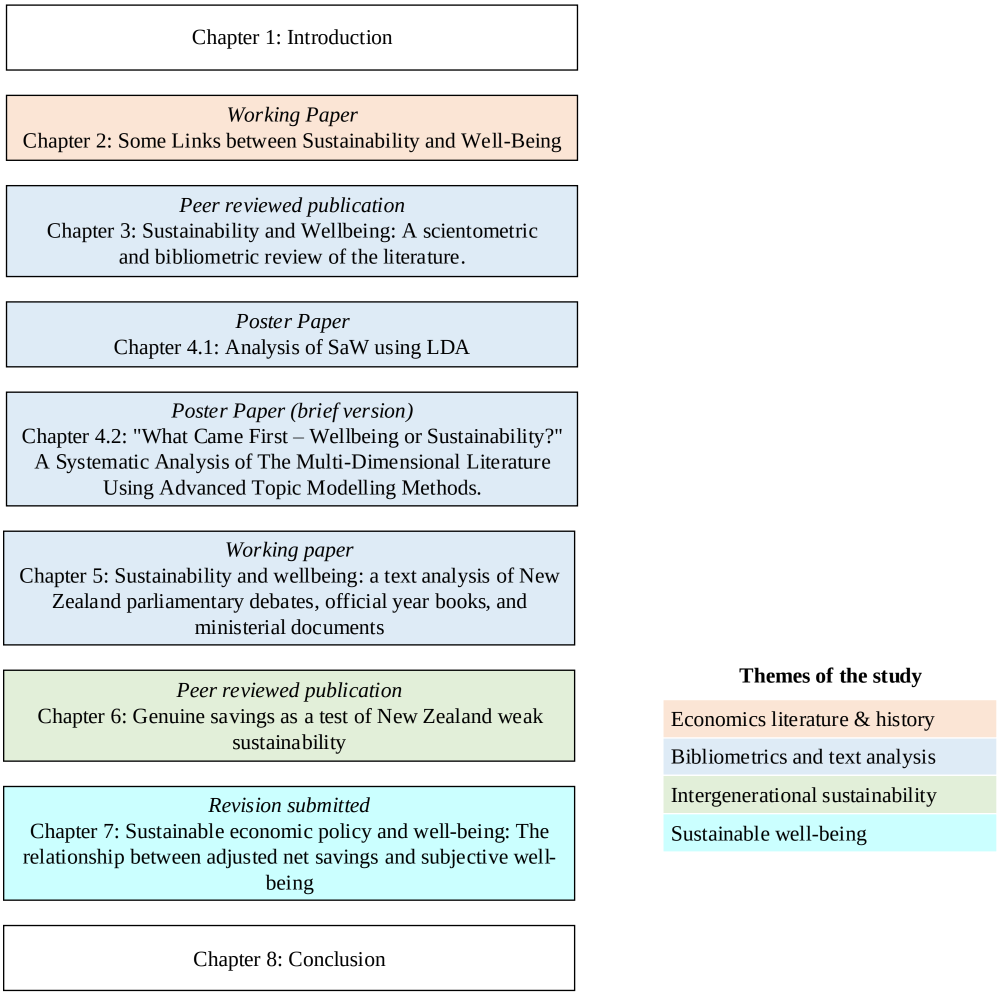
[5] Te Pūnaha Matatini is a Centre of Research Excellence hosted by the University of Auckland.
[6] International Society for Scientometrics and Informetrics.
[7] Western Economic Association International.

policymakers' toolkit. The present thesis, as the final stage of my PhD, is to bring all peer-reviewed publications and working papers into a coherent whole.

1.4 Structure of Thesis

This thesis is comprised of publications in peer-reviewed journals, a revised and resubmitted paper, a set of working papers, conference papers, and posters under four themes listed in Figure 1.

Figure 1: Structure of the thesis



In Chapter 2, we discuss the relationship between sustainability and well-being from an economic history perspective in detail to familiarise our readers with the complexity and interdisciplinarity of the subject. Chapter 3 is a bibliometric study of the SaW literature in which we try to identify the people, institutions and places leading SaW research and explore inter-linkages between them. Chapter 4 makes use of a significantly large text corpus of SaW literature to conduct a semantic analysis to identify various topics in SaW text and to describe how these topics change over time. In Chapter 5, we conduct text analysis on the text data going back 125 years from New Zealand, based upon reports of parliamentary debates, New Zealand Official Yearbooks and ministerial documents with an aim to explain the evolution of sustainability and well-being in New Zealand. Chapters 1 – 5 draw a comprehensive illustration of multi-dimensional sustainability starting from the emergence of sustainability and well-being as standalone subjects and their evolution as a unified subject matter. In Chapter 6, we adopt genuine savings as a comprehensive measure of intergenerational sustainability for New Zealand. In Chapter 7 we tested genuine savings as a predictor of future subjective well-being. Finally, Chapter 8 concludes the thesis and sets out future research direction.

1.4.1 Important note

All chapters, other than introduction and conclusion, in this thesis are standalone published or working papers on interrelated subject SaW. Each paper contains background information provided to introduce the topic to the reader (who may not have read all papers in a sequence). This may cause some repetition and overlaps across some parts of the thesis. All references to tables and figure apply within the chapter i.e. they don't refer to a table or a figure in another chapter.

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Chapter 2: Some Links between Sustainability and Well-Being

Abstract

Sustainability aims to ensure that people live their lives without compromising the well-being of future generations. Increasing well-being by providing more goods and services to consume is a sustainability challenge. There are two opposing schools of thought on the consumption of natural resources: strong sustainability and weak sustainability. Proponents of strong sustainability emphasize the preservation of natural capital in each period because they argue that it cannot be replaced with any other type of capital. By contrast, weak sustainability scholars argue that natural resource can be consumed to build other forms of capital in which case sustainability requires that the aggregated monetised value of all capital stocks is non-declining or preferably increasing over the time. In this paper, we propose to adopt a balanced approach instead of taking either of these extreme positions where critical natural capital (CNC) limits are defined by strong sustainability and, within that limit, substitutability between various types of capital is allowed for economic efficiency and growth in total wealth. In such frameworks, weak sustainability indicates the minimum sustainability requirement for an economy in which all types of capitals are substitutable under the limits of CNC.

Keywords

sustainable development
weak sustainability
strong sustainability
intergenerational well-being

JEL Classifications

I31, Q00, Q01, Q50, Q56

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2.1 Preamble

The notion of sustainability revolves around a simple and historically well-established observation: the requirement for humans to survive and thrive depends on the environment, either directly or indirectly (Marsh 1864). The environment delivers valuable services to nourish, support and sustain life, for example, breathable air, drinkable water and food. These environmental services are also required to increase the quality of life in different ways (Agarwala 2012, Ekins *et al.* 2003, Liu *et al.* 2007, Roberts *et al.* 2013). More efficient utilization of these services to satisfy human needs has been a driving force to advance knowledge (develop human capital) with respect to the use of renewable and non-renewable resources and building new materials from raw inputs (produced capital). Scarcity of natural resources has played a pivotal role in defining consumption and accumulating capital over time since continued growth requires the economy to operate below the environment's carrying capacity and its ability to replenish itself. Therefore, in a broader sense, sustainable development (SD), regardless of the definition of sustainability, necessarily deals with the stocks of various types of capitals[8] and flows to and from these stocks[9].

Thus, having more of these stocks, and consuming more goods and services from flows based on them, can be taken to define human well-being over time. Eventually the alignment of sustainability and well-being (SaW) gives rise to a unified subject matter, sustainable well-being (SW). Separately each area seeks to inform policy makers to ultimately increase human well-being under a sustainability constraint. In doing so, well-being research can improve the clarity of the goal of sustainability processes, whilst sustainability can facilitate an inclusive increase in well-being enhanced by an understanding of how capital stocks evolve and how they can be allocated efficiently to deliver maximum inter-generational well-being.

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[8] Types of capital include natural capital, produced capital (or physical capital), social capital, and human capital. Wealth of a country is estimated by converting all these capital stocks in monetary terms (Greasley *et al.* 2017). In addition, national wealth estimates include Net International Investment Position (NIIP) of a country, that is, foreign assets less foreign liabilities (Ferreira, Hamilton, and Vincent 2008).

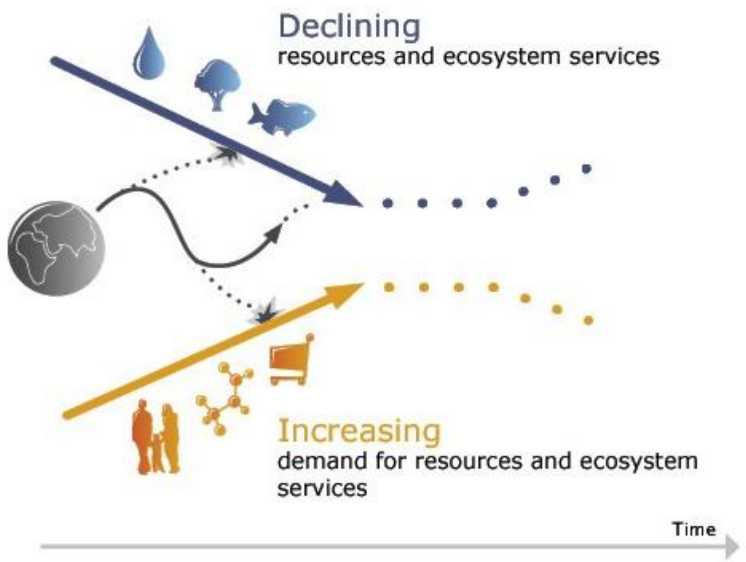
[9] The flow of the stocks stems from the production and consumption of goods and services (income/expenditure) to satisfy individual needs.

In this paper, we will discuss the concept of sustainability or sustainable development in conjunction with human well-being as a unified subject matter, and highlight the missing links between them to develop a theoretical foundation for future empirical studies.

2.2 Sustainability Challenge

An increased demand for goods and services driven by increasing population, has been reducing the capacity of the planet to supply eco-system services essential to support life and thrive sustainably (Brander 2007, Pillarisetti 2005). For example, there are fewer forests than there were 100 years ago resulting in lower capacity of the planet to provide eco-system services to support life, for example, climate regulation, water filtration, soil re-generation and so on. Meanwhile, the rate at which we consume resources and generate waste is increasing rapidly as a consequence of population growth. Abuse of power and unequal distribution of wealth further exacerbate the problem (Alesina, Tella and MacCulloch 2004, Torras 2005, Verme 2011). Metaphorically, it is as if the society is passing through a funnel of declining opportunities, and pressure is increasing with the passage of time and we have less and less margin to manoeuvre as shown in Figure 1. (Lozano 2008, Ny *et al.* 2006).

Figure 1: Resource Funnel Sustainability Challenge



Source: http://www.thenaturalstep.org/en/natural-step-funnel

If government policies and societal structures do not mitigate unsustainable behaviours, finite natural resources represented by the walls of the funnel will function as constraints on socio-economic activities. It will expose governments, institutions, or actors that continue to practise such unsustainable actions, to a systematically higher risk of hitting these funnel walls which eventually will harm their economic activity. Furthermore, these behaviours can translate into higher costs for taxes, insurance, waste management, and so on consequently reducing the overall human well-being and this vicious cycle continues to exist (Broman, Holmberg and Robört 2000, Ny *et al.* 2006).

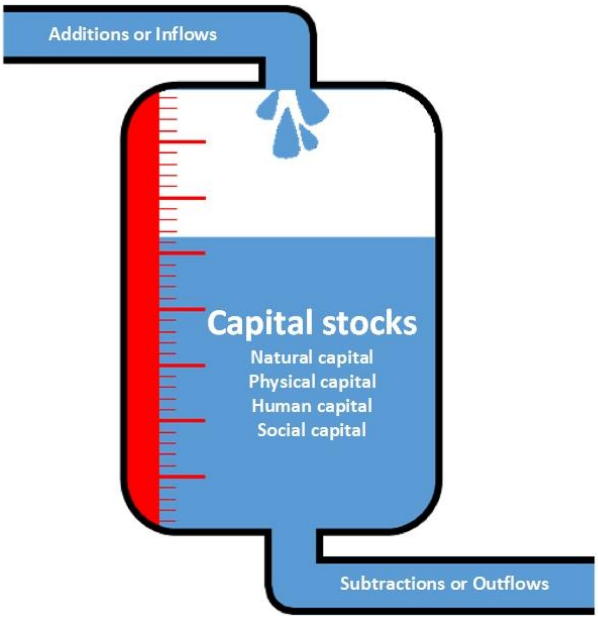
It is worth noting that the Figure 1 represents an over simplified and pessimistic sustainability challenge by recognising the importance of natural capital only (in isolation from other types of capitals). The issues become increasingly complex when produced capital, social capital and human capital are brought into the analysis. These dimensions are discussed in detailed in section 5 and 6.

2.3 Why Sustainability and Well-Being (SaW) Should Be Studied Together?

Sustainable development (SD) and human well-being have a brief and complex intellectual history. Optimal intergenerational human well-being is the foremost desired outcome of all SD endeavours; and increase in well-being of the present generation necessarily involves the utilization of resources for production and consumption[10] of good and services from the capital stocks of an economy. Managing these stocks rationally for sustained or increasing intertemporal consumption is the sustainability challenge. In other words, inflows and outflows of stocks directly contribute to income in the present and stocks are maintained to regulate these flows over the long-run. The relationship between stocks and flows of various type of capitals is illustrated in Figure 2.

[10] Utilization of resources for production of intermediate goods is a sort of consumption; therefore, both of these terms will be referred to as consumption of resources hereafter.

Figure 2: Stocks and Flows



Source: Modified work of Christoph Roser (AllAboutLean.com)

The classical economists of the late 18th century, Adam Smith, David Ricardo, John Stuart Mill, and Thomas Robert Malthus, considered land as the scarce resource which we might today classify as part of natural capital stock. They feared that the land-owners would monopolise the production processes with economic growth as location became relatively scarcer resulting in higher rents. This would eventually reduce profit margins for capital investments and shrink wages to lead stagnation, social inequality, and high unemployment. In other words, higher rents could crowd out productive investment.

For the classical economist, David Ricardo, the stock of land (which is treated as fixed natural capital) was viewed as a fundamental driver of growth and well-being. Robert Malthus (in his *Essay on the Principle of Population*) theorised that the stock of labour (unskilled human capital) and the change in this stock (given by population growth) was constrained by the productivity of the land.

However, the Industrial Revolution, driven by innovation and technological advancement, modified these fears of the Classical economists as modern machines and factories (produced capital) substituted for both unskilled labour and scarce land resources in the production process. Population increased accompanied by improvements in health via technological advancements. Later, elements associated with higher capabilities of labour (Sen 1985) through the so-called knowledge-based economy, have led to the substitution of skilled labour (which we call human capital) for all three of the previous types of capitals (i.e. natural capital, produced capital, and unskilled labour). Labour (skilled and unskilled) and physical capital are reproducible types of capital.

Similarly, some natural capital is reproducible (i.e. renewable capital such as forests). However, most natural capital is non-renewable such as minerals and energy resources. Concerns over the complete exhaustion of non-renewable natural capital are not new in resource economics. Jevons (1865) was likely the first notable economist to warn of the possible consequences of depleting a non-renewable natural capital resource (that is, coal) to meet the increasing energy demands of that time. However, with new technological advancements to meet energy demands from alternative energy resources (from renewable resources, for example, wind, solar and biomass) there is almost certainly more coal remaining in the ground than has ever been extracted.

From this discussion, it becomes clear that technological advancement plays a vital role in defining how basic types of capitals (land - natural capital), (unskilled) labour, human capital (skilled labour) and physical capital interact in the production of goods and services (for example, in a production function). It is also apparent how these interactions between various capitals have changed over time to contribute to current and future well-being from the consumption of goods and services. During the post-industrial revolution period, changes in the proportions of capitals used to create goods and services (and the utility to those that consume them) have occurred in response to changing relative prices, operating within some form of market.

Until quite recently, the size of these stocks of capitals (wealth) and the rates at which they change, have typically not concerned most governments or agents (exceptions include Jevons' (1865) concern with coal; recognition of declining fish stocks in the North Sea, and latterly a popular belief in 'peak oil'). Part of the reason might be the fact that the governments have been more interested in measuring the flows derived from the stocks (i.e. current income/expenditure) via the System of National Accounts (SNA). This includes changes in Gross Domestic Product

(GDP[11]) or real GDP per capita (which takes population growth into account) which has sometimes been used as a proxy measure of well-being. Maximising changes (or reducing fluctuations) in these marketed flows of monetised values of goods and services has been advocated by many as ‘the goal’ of representative governments. Such measures could proxy for the utility received from these goods and services to some degree when non-market elements are excluded (Kuznets 1951, Stiglitz *et al.* 2010), but they fail to take account of non-market goods and services (which contribute to well-being) or changes in capital stocks (which are key to long-term sustainability). A narrow focus on GDP contradicts Adam Smith’s focus on the *Wealth of Nations* as opposed to the income of nations.

2.4 Why are Sustainability and Well-Being Studied Independently?

Well-being and sustainability have generally been studied as independent subjects historically despite their intertwined nature. This has led to several gaps within SaW research (Helne and Hirvilammi 2015). As a result, despite SD being a catchword among policy makers for over four decades since the Brundtland Report (Bruntland *et al.* 1987), the actual progression towards a complete understanding of both sustainability and well-being is still in its infancy.

Questions around the contribution of economic development to human well-being has been a vital subject of the SaW debate for decades (Easterlin 1974, 2005, Easterlin *et al.* 2010, Grimes and Reinhardt 2015, Grimes *et al.* 2016, Qasim and Grimes 2018, Stevenson and Wolfers 2008, Stiglitz *et al.* 2010, Verme 2011). Contradicting arguments of the debate include varying definitions and measures of SaW (for example, measuring well-being in terms of economic welfare, job security, standards of living, personal happiness) and different interpretations from

[11] Built on the noble prize winning work of Richard Stone on the system of national accounts, GDP was ‘invented’ in the US in the 1930s and was acclaimed as a significant achievement. This new system of annual estimates of gross national product was used initially for wartime (WWII) planning and were seen as having the potential to identify where an economy is in terms of a business cycle and potentially for governments to smooth out peaks and troughs. GDP accounting was never seen as an indicator or instrument designed to foster long run (sustainable) economic development, but more as a tool to identify how the economy was changing over short periods of time in terms of monetised production, where positive annual changes in the growth rate were/are seen as a goal in their own right and as a metric for international benchmarking and measures of success. Importantly, one of the key founders of GDP accounting, Simon Kuznets did not see GDP as a goal to be maximized. See Kuznets (1951) for details.

historical evidence. Whilst the debate on the relationship between economic development and well-being continues, there is general agreement that economic growth alone (as measured by GDP and other similar indicators) is not a perfect measure of well-being.

Both sustainability and well-being are seen as complex multi-dimensional notions for monitoring and evaluation. When it comes to assessing the performance of economies in terms of SaW, the majority of sustainability indicators fail to consider overall well-being (that is, Ecological Footprint, EF) and most well-being indicators ignore sustainability (that is, the Human Development Indicator, HDI) (Qasim 2017). Some indicators like the Index of Sustainable Economic Welfare (ISEW) and Genuine Progress Indicator (GPI) attempt to fully integrate SaW, at least in theory. However these indicators do not portray the richness of well-being dimensions and also miss particular aspects of sustainability, so do not present the whole picture (Neumayer 2007).

Part of the reason for this outcome is that historically, sustainability and well-being research have evolved as independent subjects. The roots of well-being are found mainly in the literature of philosophy, psychology, sociology, and medicine. In contrast, early SD research focused on the triple bottom-line, that is, economy, environment and society and thus predominantly emerged from interdisciplinary social sciences (Qasim 2017). In recent studies, the vitality of human well-being has been recognised as an outcome of SD. To this end, this paper presents key concepts, definitions, and developments in the fields of multidimensional SaW in relation to each other. We highlight the fundamental missing links between them and develop a case as to why SaW should be studied as a unified subject. The work will develop the foundations of the present project to link, and empirically assess, SaW in the following chapters.

2.5 Sustainable Development

The phrase ‘Sustainable development’ (SD) (and its converse) is a concept with many possible meanings, interpretations, consequences, causes and solutions. It is sometimes interpreted as sustained growth, sustained positive change, or simply successful development (Lélé 1991). According to O’Riordan (1985) SD is a ‘contradiction in terms’. These differences in interpretations have both conceptual and semantic roots. For example, most people use the phrase sustainable development interchangeably for ecologically/environmentally sound development (Tolba 1984). Such an interpretation can be characterised by: (1) understanding sustainability as ecological/environmental sustainability or (2) conceptualising sustainability as a process which includes ecological/environmental sustainability as a component. Because of the broad, range of concepts and definitions around SD, it is imperative to attempt to consolidate SD theory to rigorously define what sustainability is, before attempting any meaningful empirical analysis.

2.5.1 Brief Intellectual History of Sustainability

It is very hard to say when the phrase *'sustainable development'* was first used. Historically, the roots of sustainability (in the context of sustainable development) are grounded in six independent but related strands of thought which predominantly emerged from three interconnected topics during the 1950s relating to: (1) population growth, (2) use of resources and (3) limits to growth. They six strands of thought are: (a) carrying capacity, (b) environment and resources, (c) biosphere, (d) no/slow growth, (e) eco-development, and (f) technological advancement. All of these strands of thought were well-established before the word *'sustainable'* itself was used. The word *'sustainability'* was used in 1972 in a British book, *Blueprint for Survival* in relation to the future of human society. In 1974, the word *'sustainability'* was used in the United States to rationalise a 'no growth' economic development. *'Sustainability'* was used in 1978 in the United Nations report to elaborate *'ecodevelopment'*. By the end of the 1970s the term *'Sustainability'* started to be widely used in technical reports and policy documents to explain a wide range of strands of thought (Kidd 1992).

The 'overpopulation' school of thought descends directly from the Malthusian notion of population growth proposed in *An Essay on the Principle of Population* by Robert Malthus in 1798 in which he focuses on population growth as an underlying cause of resource overuse and environmental degradation. His basic idea was that the population grows at a geometric rate, whereas food supply grows at an arithmetic rate leading to the occurrence of severe food shortage followed by starvation, deaths, and epidemics which eventually wipe out the surplus population and re-establishes equilibrium in society. Although global population continues to rise, and most sustainability models account for population growth, concerns over overpopulation have been retreating due to high incomes, low fertility rates (in some, but not all, countries), and technological advancements (Brander 2007).

Consideration of the use of resources mainly deals with concerns about environmental degradation (such as air and water pollution), and depletion of renewable (for example, forest) and non-renewable (for example, coal, oil, gas, minerals) natural resources. Sustainability models in two distinct (but overlapping) fields of economics i.e. environmental economics and resources economics, addresses natural capital in terms of *stocks and flows* for *wealth* accounting and *income* accounting. These concepts are discussed in detail later in the paper.

The *'No growth'* philosophy emerged comprehensively and forcefully in the 1970s after the work Georgescu-Roegen (1971). In his book, *The Entropy Law and the Economic Process,* he emphasised that the steady-state[12] is inevitable for an economy following the fundamental laws of thermodynamics. In steady-state growth stage, by definition, the quantity of resources is constant and the inflow and outflow must balance (Ayres 1999). This was followed by the notion of *'Limits to growth'* by (Meadows *et al.*1972).

Similar to Malthusian theory, Meadows *et al.* (1972) argues that the vital substance of the *'Limits to growth'* approach is that the world is set for a collapse through population growth, depletion of natural resources, pollution, environmental degradation, or a combination of these, within a few decades. Results of their computer simulations showed that, if present growth trends remain unchanged, the planet will reach its limit in the next 100 years (that is, by 2072 since the book was first published) leading to a catastrophic future unless drastic actions, including cessation of economic growth, are taken. It is also worth noting that most of the natural resources included in their computer models (that is, coal, oil, gas) were

[12] Steady-state growth for an economy is one of the most fundamental critiques of traditional economics from a sustainability perspective. In his book, Steady-State Economic Growth, Daly (1977) argues that endless growth for an economy in physical production is not possible and it grows qualitatively rather than quantitatively beyond steady-state.

predicted to be exhausted well before now (2018) nevertheless none of them have been, showing the falsity of the approach.

Following the above three topics and six strands of thought, the term 'sustainability' became widely used in resource economics, environmental economics, and in related policy documents, by late 1970s. Unfortunately, the term was used ambiguously (that is, in a variety of ways), which led to a significant semantic confusion (Brander 2007, Özdemir *et al.* 2011). However, it was somewhat agreed that the majority of sustainability approaches include environmental aspects in economic growth models by restricting the depletion of natural resources. The debates on the perception about the interactions between environmental health and economic growth and the extent to which natural capital could be allowed to be harvested in order to achieve higher quality of life led to the paradigms of ***weak sustainability*** and ***strong sustainability***. These are discussed in detail later in this paper.

The origins of SD were raised in 1930s in economics by (Hotelling 1931)[13] and in 1970s by (Dasgupta and Heal 1974, Solow 1974, Stiglitz 1980), which has been referred to as the 'Dasgupta-Heal-Solow-Stiglitz (DHSS)' approach in (Hamilton and Withagen 2007) and was expanded by (Pearce, Markandya and Barbier 1989)[14].

The modern concept of sustainability was emphasised and popularised in 1987 by the United Nation's Brundtland Commission Report (Brundtland *et al.*

[13] In his paper, 'The economics of exhaustible resources', Hotelling (1931) models 'a non-renewable, exhaustible resources with completely known stock, where no new discoveries are possible, there are no alternatives, no recycling, private ownership and constant costs of extraction…' and concludes that, 'the price of the resource will increase at the interest rate over time.'

Empirical results, on the contrary, have shown that prices for most depletable resources do not seem to follow ever increasing Hotelling price path ever over very long time-horizons. The key reasons for the empirical falsification appears to be that the restrictions assumed to create the Hotelling Rule do not all apply. Once these restrictions are eliminated or relaxed, the result can be either an increase or decrease in resource price over time.

However, in a general sense the 'Hotelling Rule' is about the rationing role of prices in markets where price signals reflect scarcity of resources. Any attempts to influence prices for other issues, may mean that the rationing signals are distorted.

[14] All of this work discussed in detail later in this chapter.

1987), *Our Common Future* which presented the concept of SD to the global community as a new paradigm for economic expansion, environmental sustainability and social viability. The Brundtland Commission 1987 Report defines sustainable development as:

'the development that meets the needs of the present without compromising the ability of future generations to meet their own needs.'

It further argues that *'the environment'* is where we live and *'development'* is what we all do in order to improve our lives and these two are inseparable. SD according to Brundtland involves two key concepts:

(1) 'The concept of 'needs', in particular, the essential needs of the world's poor, to which overriding priority should be given, and
(2) The idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs.'

Later, in 1993, US President Clinton endorsed the idea of SD stating: 'If we do not nurture our people and our planet through sustainable development, we will deepen conflict and waste the very wonders that make our efforts worth doing.'[15] In 2000, sustainable development became an integral part of the United Nations' Millennium Development Goals (MDGs) and emerged as a shared vision of the governments around the world. Recently, sustainable development has been seen as a study of critical links between the allocation and distribution of a wide range of resources in order to ensure that our current actions are consistent with our future aims (UN, 2012).

'The long-term vision of the High-level Panel on Global Sustainability is to eradicate poverty, reduce inequality and make growth inclusive, and production and consumption more sustainable, while combating climate change and respecting a range of other planetary boundaries.' (UN, 2012) Pg.10

In 2016, on the back of the success of the MDGs, 17 Sustainable Development Goals (SDGs), also known as 'Global Goals' have been introduced by the United Nation's Development Programme which include new areas of development such

15 http://www.state.gov/p/io/potusunga/207375.htm

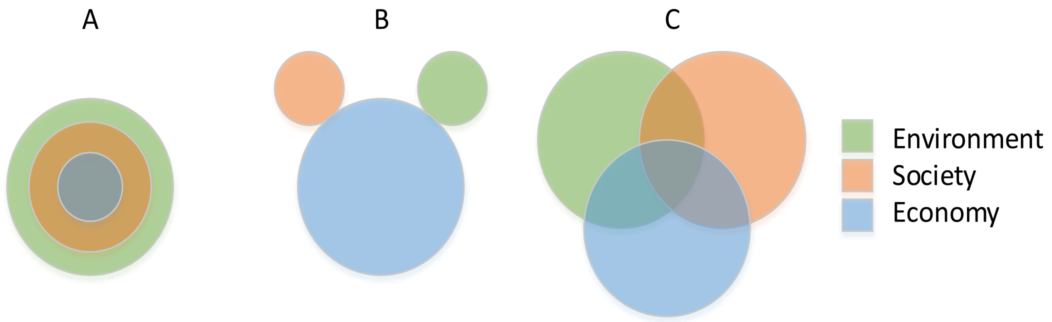
as innovation, climate change, economic inequality, sustainable consumption, peace and justice, among other priorities. These goals, to be attained by 2030, have been adopted by the governments of some 170 countries (Griggs *et al.* 2013).

In a broader sense, positive sustainability in the literature is seen as study of: the dynamic optimality, intergenerational neutrality and interlinkages between the economy and the environment which puts social equity within and between countries at the core of SD. Although SD has been a visionary paradigm over the last several decades for governments, civil society, and businesses around the world, the concept itself remains elusive across disciplines and its implementation has proven hard (Drexhage and Murphy 2010, Lélé 1991, Quiggin 1997, Tisdell 1988, 1993). It is largely agreed that SD necessitates the convergence between its three pillars: (1) economic development, (2) social equity and (3) environmental protection. The differences and inconsistencies in conceptualizing SD are rooted in perceiving the overlaps between them.

For example, neoclassical economics typically evaluates policies based on their welfare outcome where welfare is sometimes equated with consumption (Safarzyńska 2013). Sustainability theories of neoclassic economics have been criticised by new and emerging disciplines in economics, environmental sustainability, and behavioural studies. For instance, sustainable consumption in neoclassical economics is built around the notion of market equilibrium, utility maximization and preferences which are inadequate to guide policy prescriptions in the presence of dynamic preferences, uncertainties and complex socio-economic interactions (Akerlof and Shiller 2010, Bergh and Kallis 2009, Binder and Witt 2011, Farmer and Foley 2009, Gowdy 2005, Ostrom 2008).

Others argue that ecological modernization concepts with an emphasis on efficiency and innovation cannot guarantee to meet Brundtland's sustainability criteria. For instance, Lorek and Spangenberg (2014) argue that the concept of sustainability has been unfortunately weakened, misunderstood and misinterpreted by green economy/green growth theories since its formation. Nations are, therefore, hardly approaching it and current trends are moving in the opposite direction. These diverging arguments on sustainability and well-being are grounded in the varying arrangements of three pillars of sustainability (which are widely discussed in sustainability literature (Daly 1996, Ekins and Medhurst 2006, Ekins 2011, Elkington 1998, Jickling *et al.* 2011, Mulia, Behura and Kar, 2016) summarised in Figure 3.

Figure 3: Commonly Used Sustainability Models



A: THE BULLSEYE SUSTAINABILITY MODEL
B: THE 'MICKEY MOUSE' SUSTAINABILITY MODEL
C: VENN DIAGRAM SUSTAINABILITY MODEL

SOURCE: FIGURE COMPILED FROM MULTIPLE RESOURCES.

The 'bullseye' sustainability model on the left in Figure 3 recognises the economy as a subset of a society and both of these are entirely dependent on the environment. Economy exists within the society due to the fact that a significant proportion of society does not contribute to economic activity. In this model, society and the economy combined operate within the natural limits of the environment (for details see Daly (1996). This model has also been referred to as strong sustainability model (although it allows some degree of substitutability between natural capital and other forms of capital).

In the middle of Figure 3, Model B (the 'Mickey Mouse' model) focuses on the economy as the most important pillar of sustainability with society and the environment as minor side issues (Houck 2003, Mann 2018, SANZ 2009). It reflects anthropocentric behaviours where economic activities predominantly influence the environmental and social bottom-lines (Mulia, Behura and Kar 2016). Model C on the right (a Venn diagram or a standard triple bottom-line model) was proposed by (Elkington 1998) to illustrate the relationship between the three pillars of sustainability. Models B ignores the ultimate limits of Model A imposed by the environment (biosphere) on the economic and social pillars of sustainability and thus indicates a growth economy which make them weak sustainability models

(Lozano 2008). By contrast, if the economy in model C is operating in the intersection area, then it is operating within the natural boundaries.

In the following section, we try to narrow down the definition of sustainable development leading to human-well-being in the field of economics by classifying and categorizing overlapping concepts.

2.5.2 Sustainability Revisited in Modern Economics

Although modern economic models of sustainable development limit the scope of objectives, they maintain internal consistency. The economic approach to sustainability is based upon maximizing intertemporal welfare, where the constrained optimization problem includes system interlinkages and refrains from intertemporal discrimination. In other words, sustainability in an economic perspective rests on three pillars of inter-generational equity, interlinkages between environment and economy 'environomy' and dynamic optimization (Stavins, Wagner and Wagner 2003). Economists began with a modest specification of interlinkages, where production is taken as a function of natural resource extraction, capital and labour (which in some cases may be represented by a Cobb-Douglas production function).

According to Endress and Roumasset (1994), Endress *et al.*(2014) and Endress, Roumasset and Zhou (2005) adding intergenerational equity into the function results in two main rules for sustainable and optimal growth: (1) extract natural resources in accordance with the principle for **optimal resource management**; (2) **accumulate genuine savings** guided by the Ramsey condition for optimal savings and investment. Combination of these two principles provides a decomposition of the sum of natural capital and produced capital (used in the Genuine Savings measure for example) and an optimal consumption path. This optimal path is sustainable even in the absence of a sustainability constraint, which requires non-declining consumption over-time (Pezzey 1997) or non-declining intertemporal welfare (Arrow *et al.* 2004). Optimal consumption continually rises and approaches the Golden Rule level[16] (Endress and Roumasset 1994).

[16] The golden rule is defined as the growth path which returns the highest indefinitely maintainable level of consumption per capita (Phelps 1961). It clearly contains the concept of sustainability

These models can be extended further by including externalities, such as pollution growth, greenhouse gas emissions, under the same optimality condition of the Ramsey equation and the Pearce equation (Endress, Roumasset and Zhou 2005, Endress *et al.*2014). Therefore, sustainable development does not require to abandon fundamental principles of economics as in the popularised approaches. Optimal growth theory, for sustainable development, only requires the combination of recognised economic principles (Endress, Roumasset and Zhou 2005). The debate between ecological modernisation and optimal growth has led to the categorisation of sustainability under strong sustainability and weak sustainability discussed in the following section.

2.6 Types of Sustainability

The idea of sustainable development is tempting. It has evolved as a development catchword and become one of the key challenges of the century. The term itself, however, has resisted unanimously acceptance (Clark 2007, Dietz and Neumayer 2007, Sachs 2005). Though there is considerable political consensus on the notion of sustainability, the scientific consensus regarding the fundamental question 'what to sustain?' (Arrow *et al.* 2012, Dobson 1996, Robert, Parris and Leiserowitz, 2005, Stone, 2003) has still not been reached (Brand 2009). We must discriminate between a number of approaches in order to reach a substantive definition (Neumayer 2007). As mentioned earlier, in economics, one debate is over what sort of capitals ought to be preserved for current and future generations (Arrow *et al.* 2012, Costanza *et al.* 2007). At a conceptual level, this is the choice between strong sustainability and weak sustainability (Pezzey and Toman 2002), a classic dispute between Solow (1974) and Georgescu-Roegen (1971).

2.6.1 Strong Sustainability

Strong sustainability is hard to define unambiguously, although it is based on the notion that views natural capital to a greater and lesser extent non-substitutable in the production processes. It defends the critical role of natural capital due to its unique contribution for sustenance and well-being (environment, eco-system

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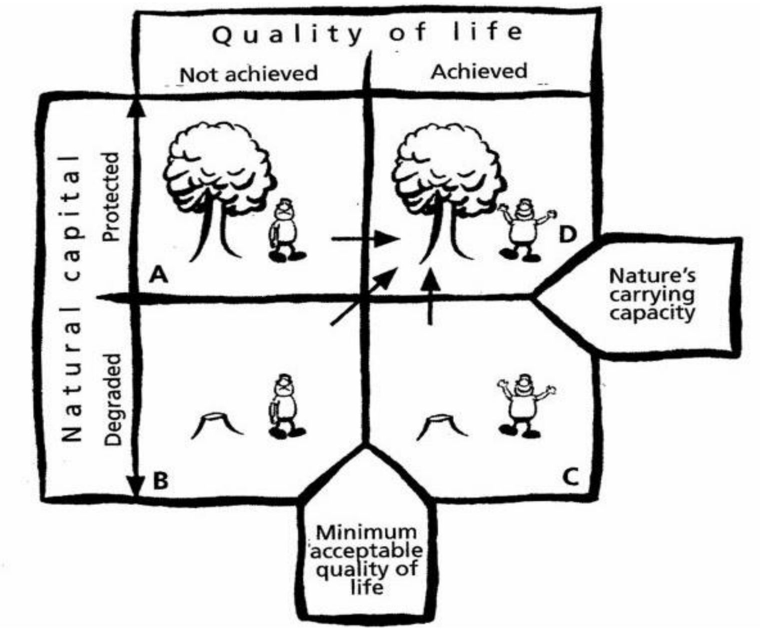
implicitly, that is, the golden rule path is the sustainable development path (Chichilnisky, Heal and Beltratti 1995 and Parker 1999).

services) and holds that it is non-substitutable with any other type of capital (for example, produced capital, social capital). Thus, all types of capitals should be independently maintained. In this paradigm, any development process which does not preserve natural capital is bound to lead towards an unsustainable growth path (Mulia, Behura and Kar 2016, Neumayer 2003). Strong sustainability aims at box D in Figure 4 where the quality of life is achieved without tapping into natural capital as the only sustainable solution. Whereas in weak sustainability, box C is also acceptable as long as net aggregate value in monetised terms of all types of capital is larger than the value of the degraded environment, or outputs are greater than inputs.

Strong sustainability is mainly favoured by the environmentalists who explain the function of natural capital under four broad categories: (1) it provides raw materials for production and consumption; (2) it assimilates waste associated with consumption and production; (3) it provides eco-system services and (4) it provides basic life support functions (Ekins *et al.* 2003, Pearce and Turner 1990, Roberts *et al.* 2013). The fourth category, therefore, is not only a direct determinant of human welfare, but also provides foundation to the first three categories. The substitution between the first and second categories of natural capital and produced capital may be possible, to some extent, with high production efficiencies and advanced waste management technologies. However, the basic life support feature of natural capital is certainly not substitutable and, therefore, development should be subjected to strong sustainability rule (Dietz and Neumayer 2007 and Roberts *et al.* 2013).

Figure 4: Sustainability and Quality of Life (Human Well-Being)



SOURCE: COLORADO COLLEGE,
http://www.coloradocollege.edu/dept/ev/courses/footprint/Footprint.htm

'Very strong' sustainability (backed by the Deep Ecology movement and supported by those who believe in the 'right-to-life' for all forms of life) implies that every element or sub-system of natural capital, all species, and physical stocks, must be preserved (Pearce and Atkinson 1995). Some have also included a 'neo-Marxist' political economy perspective in to the strong sustainability argument which opposes economic modernization theories and stresses the fundamental trade-offs between economic production and eco-system services. Under such scenarios, the solution lies in diverting sustainability policies from economic expansion towards ecological sustainability.

2.6.2 Weak Sustainability

The notion of weak sustainability emerged from the neo-classical economic strand of though (Pearce and Atkinson 1993). In this view it is assumed that any economic activity can be sustainable provided that the total output value (aggregated from the monetised value of all types of capitals) is greater than the input value used in the production processes. Thus, weak sustainability implies all types of capitals discussed earlier are interchangeable. Economic modernisation theory stemming from neo-classical economics, argues that the environmental degradation caused by economic growth can be compensated for with the development of other types of capitals (for example, human capital, produced capital). Skilled human capital and technological advancements, in the future, will not only help to reduce the environmental impacts more effectively, but also improve production efficiencies. Thus, the economic modernisation theory does not view a fundamental conflict between economic modernisation and utilisation if the environment over the long-run (Ayres *et al.* 1998, Dietz and Neumayer 2007).

The origins of weak sustainability are found in the 1970s (Neumayer 2007) when neoclassic models of economic growth were extended to account for non-renewable natural capital as a factor of production (Dasgupta and 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 on how much of it to consume and how much should be invested in produced capital for future consumption. The key question posed with these models was whether the optimal growth is sustainable in the sense of non-declining well-being, which proved to be infeasible in a certain class of models which include a non-renewable resource as a factor of production. In these models, 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 a 'rule of thumb' that the rents produced from the depletion of non-renewable resource should be reinvested in the produced capital. This could be considered as a general rule of weak sustainability such that the rate of change of net capital investment, which includes gross investment in all types of capital, is measurable, and subtractable from depreciation or consumption, is not allowed to be negative (Hamilton 1994).

The Hartwick and Solow models impute renewable and non-renewable resources in a Cobb-Douglas production function which is characterised 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: (1) natural resources are abundant or (2) the elasticity of substitution between natural capital and produced capital is equal to or great than unity; (3) technological advancement can boost productivity of natural capital at a higher rate than its depletion (Dietz and Neumayer 2007).

In order to measure weak sustainability, we need to enter the realm of green accounting. In other words, we have to associate economic values to the reduction in the quantity of natural capital and to environmental degradation, that is, the economic value of damage to natural capital quality. This enables planners to correctly understand if the natural capital losses are being compensated equivalently, or not. Commonly used measures of weak sustainability include environmentally-adjusted net product; genuine savings (GS); measures of resource depletion; measures of environmental degradation and the index of sustainable economic welfare (Asheim 1994, Dietz and Neumayer 2007, Pearce and Atkinson 1993, Quiggin 1997, Romero and Linares 2014).

2.6.3 Are Strong and Weak Sustainability Conflicting Paradigms?

To many, an unambiguous answer to this question is 'yes'. According to (Pearce, Markandya and Barbier 1989), however, this is not the case. In *Blueprint for a Green Economy* they define SD as a situation where *well-being for a given population is not declining, or preferably is increasing over time* (Pearce, Markandya and Barbier 1989). They suggest that such SD requires that each generation passes-on undiminished stocks of total capital to the future generation in order to meet intergenerational fairness and non-declining consumption over time. They emphasised the extent to which a decline in natural capital (for example, loss of forest) can be compensated for by increasing other forms of capital (for example, human capital, produced capital) leading to the following cases for intergenerational rule:

(1) SD requires non-declining total wealth (weak sustainability condition).
(2) SD requires non-declining natural wealth (strong sustainability condition).

They further explain the following reasons why we need to impose rules on the strong sustainability condition rather than the weak sustainability condition.

(a) Lack of sufficient substitutability
(b) Irreversibility

(c) Uncertainty and
(d) Intra-generational equity[17]

In weak sustainability[18], the natural capital stock is maintained as non-declining (in the long-run) slightly differently by compensating for the net value of environmental damages (Rule 1). When evaluated at the programme level, this value of net environmental damage should be zero or negative, either when discounted across multiple time periods or at each point in time as suggested by the Hartwick general rule. According to (Pearce, Markandya and Barbier 1989), this could be achieved by commissioning shadow projects which have the purpose of off-setting environmental damages from other projects in the programme. Such shadow projects might well yield negative NPVs when appraised in isolation, implying that there is a sustainability 'price' being paid by the economy, which is the marginal cost of the constraint of no positive environmental damage.

2.7 Balanced Sustainability Approach

The debate between the proponents of weak sustainability and strong sustainability continues today. Although there are many possibilities for substitutions and major breakthroughs, strong sustainability might seems sensible to some, but it the concept undermines the role that technological advancement and skilled human capital can play particularly over the long-run (Ayres 1999 and Daly 1997).

Since strong sustainability is a more rigid concept, a number of rules have been suggested to operationalise it. Neumayer (2003) has identified two different school of thoughts. One requires that the value of natural capital is preserved under the assumption of unlimited substitutability (for weak sustainability) among different forms of capital. In the case of non-renewable natural resources, for instance, extraction should be compensated by the investment in renewable natural resource of the same or higher value. The second school of thought requires that a

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[17] This is due to the reason that the poor are often more adversely affected by the degraded environment than the rich (Costello *et al.* 2009, Mendelsohn, Dinar and Williams 2006).

[18] Pearce, Markandya and Barbier (1989) used terms weak sustainability and strong sustainability slightly differently. According to them, the former is the situation where the net environmental cost of implementing a portfolio of projects is zero or negative across projects in the portfolio over time. In the latter, they require this non-positive condition to hold for each single time period.

subset of total natural capital should be preserved in physical terms so that its functions remain intact. This is called ***critical natural capital*** (CNC) (Brand 2009, Dietz and Neumayer 2007, Ekins *et al.* 2003, Neumayer 2003).

CNC is largely defined as 'the minimum amount of natural capital which is required for important environmental functions and which cannot be substituted in the provision of these functions by any other form of capital' (Douguet and O'Connor 2003, Ekins 2011, Ekins *et al.* 2003) and the maintenance of CNC is one of the key aspects of SD which is essential (Brand 2009, Ekins *et al.* 2003). According to Turner (1993), the constraint of critical natural capital is required to be maintained within bounds to be consistent with the ecosystem stability and resilience. Depletion of natural capital beyond a critical limit, results in irreversible loss (for example, extinction of an entire species) which could entail enormous costs due to its vital role for human well-being; and it could be highly unethical (Dietz and Neumayer 2007).

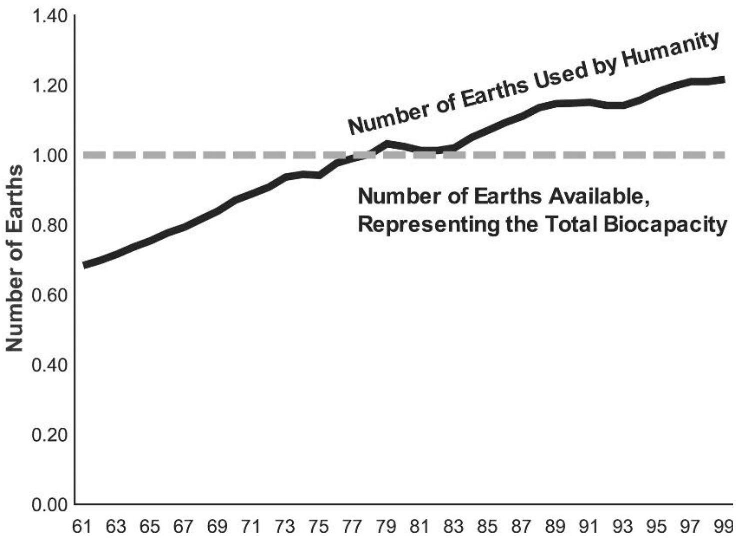
If the environmental limits are exceeded (that is, depletion of natural capital beyond CNC) weak sustainability also becomes indefensible (Arrow *et al.* 1995). Environmental conservatives have suggested that production processes have already exceeded earth's carrying capacity resulting in ecological overshoot[19] (Wackernagel *et al.* 2002). According to their work, overshooting occurred around the 1980s and during the following two decades, until the late 1990s, when this amount reached 1.2 as show in Figure 5. Similarly, the National Footprint Accounts annual trends, published by Global Footprint Network shown in Figure 6, reveals that every coming year is bringing 'overshoot day' (in illustrative calendar date when consumption of resources for the year exceeds the planetary capacity to re-generate those resources and assimilate waste for that that year[20]) earlier than the previous year. This day fell on 2 August in 2017 see https://www.overshootday.org/); and at the current rates of consumption, we would need 1.7 earth like planets to off-set those footprints.

[19] Ecological overshoot is one of the major concepts among the supporters of strong sustainability of the sustainability, this occurs when natural capital is harvested at a faster rate than it regenerates which could lead to depleting the stocks of natural capital (Wackernagel *et al.* 2002).

[20] $Earth\ overshoot\ day = \frac{World\ bio\ capacity}{World\ ecological\ footprint} \times 365$

While recognising some concerns of the strong sustainability believers, proponents of weak sustainability emphasise on the total wealth which includes all other types of capital as well (Arrow *et al.* 2012, Ferreira, Hamilton and Vincent 2008, Greasley *et al.* 2014). As long as total wealth is increasing, societies are on a sustainable development path. For example, the Human Development Index (HDI) global mean (compiled by the UNDP as a broader measure for quality of life) has been increasing since the 1990's as shown in Figure 7. This trend contradicts the rigid pessimism by overshoot theorists. If global population has been over consuming natural resources unsustainably for the last four decades, some of its adversities should have been reflected in the HDI trends. Dietz and Neumayer (2007) also criticised strong sustainability assumptions in EF frameworks of sustainability, for similar reasons[21].

Figure 5: Ecological Overshoot of the Economy



SOURCE: (Wackernagel *et al.* 2002)

[21] This paragraph rests on the assumption that HDI a good measure of well-being. Other composite measures of well-being, such as the Legatum Prosperity Index and the OECD's Better Life Index also show no sign of reduction in broadly measured well-being over time.

Figure 6: Annual Trends in Earth Overshoot Day

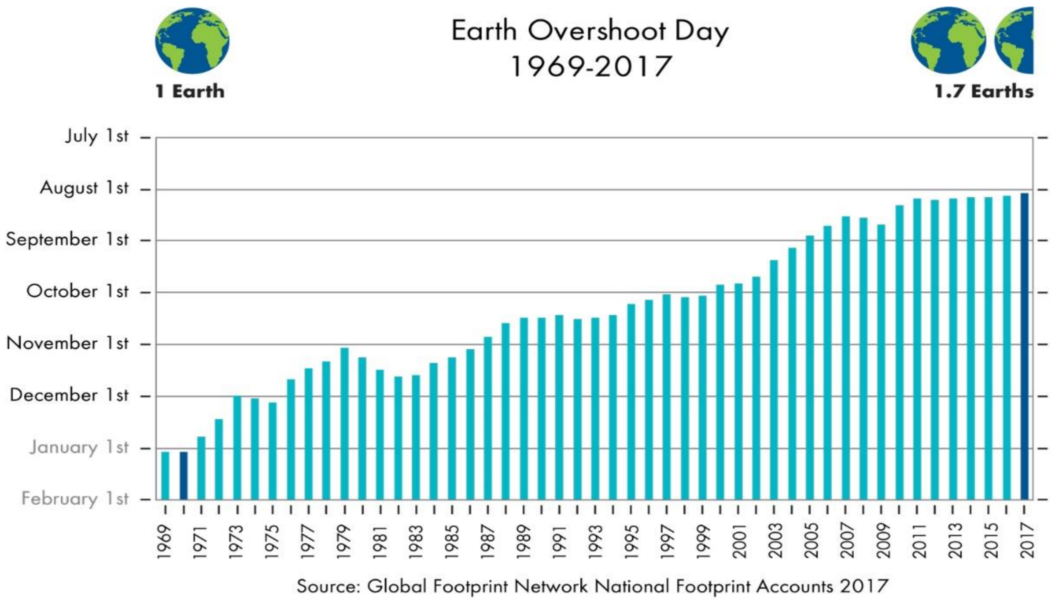
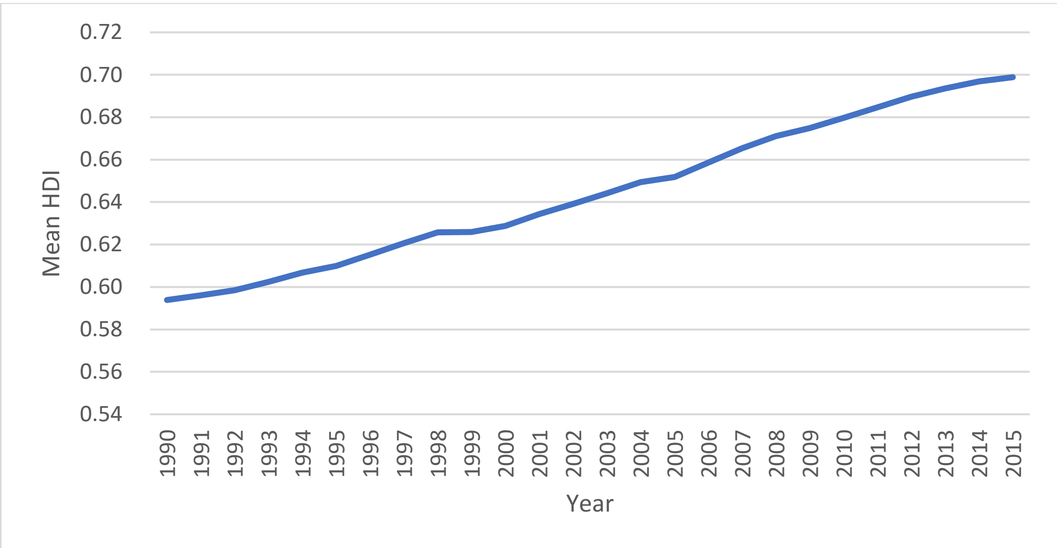


Figure 7: Tends in Global Mean HDI



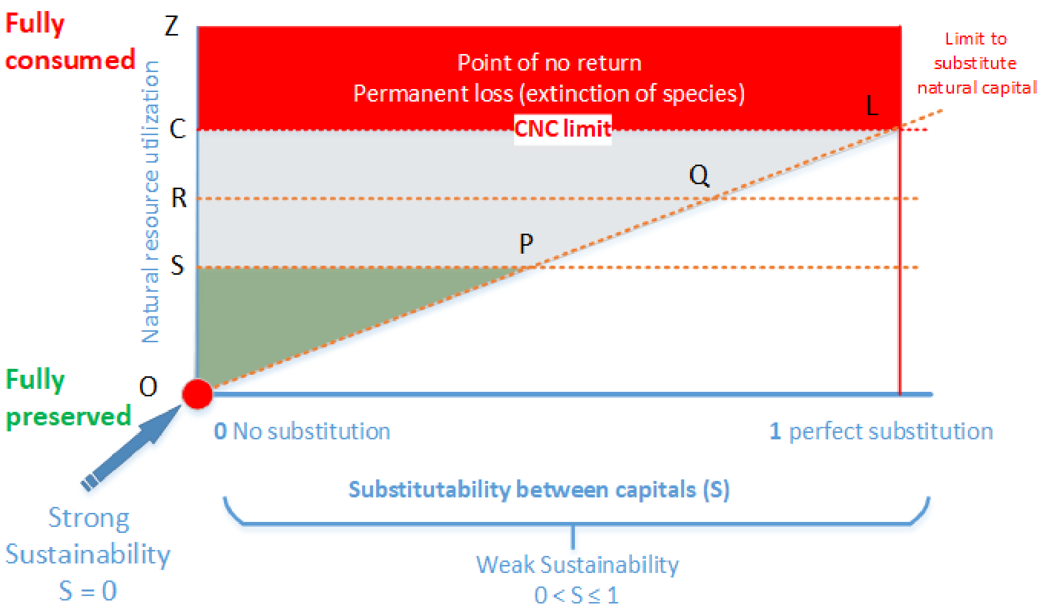
Source: PLOTTED FROM THE DATA AT HTTP://HDR.UNDP.ORG/EN/DATA#

On the other hand, the key reason for which weak sustainability is criticised is that it overlooks CNC limits in unlimited substitution possibilities. This shortcoming has been recognised as suggesting that the weak sustainability frameworks and their monitoring and evaluation indicators, should be consistent with protecting CNC (Dietz and Neumayer 2007).

Our argument is that taking either of these two extreme positions of weak sustainability's infinite substitutability, or strong sustainability's ecological superiority is unnecessary. Instead, adoption of a middle way between them is the most coherent approach. That is, some degree of substitutability between various types of capital should be allowed and ***renewable natural*** capital can be harvested below the CNC limit to develop other types of capital (Romero and Linares 2014). Our proposed concept is illustrated in Figure 8. The x-axis shows substitutability between natural capital and other types of capitals from 0 (no substitution) to 1 (perfect substitution); and natural capital utilisation is shown along the y-axis from O (state of fully preserved natural capital) to Z (state of fully consumed natural capital). In this figure, strong sustainability is shown as a corner solution in which any substitution between various capitals is not allowed and where natural capital is not consumed at all.

Before proceeding with further discussion, two of the key characteristics of renewable natural capital important to understand are: (1) it is wasted (in productive terms) through natural processes if not consumed (for example, fallen, diseased or dead trees in a forest) and (2) resilience of renewable natural capital (which has an ability to rebuild itself to its initial state or to a new equilibrium state in a habitat if harvested under certain limits). These characteristics are shown by points S and R respectively in the diagram. Therefore, area OSP represents the amount of natural capital which will be lost if not used; and area ORQ is the amount of natural capital that can be consumed without causing permanent harm. Area OCL under the CNC limit is the maximum range to allow substitution for weak sustainability.

Figure 8: Balanced Sustainability Concept



Source: Authors.

2.8 Conclusions

In this paper we reviewed some of the seminal sustainability literature, from the emergence of the concept itself and tracked its historical developments over time. We also shed some light on why human well-being, which is the foremost desirable outcome of all sustainability endeavours, has been excluded from most sustainability models. One of the key reasons is that the term 'sustainability' has been the focal debate between environmentalists, ecologists and economists. This is a debate of the substitutability between various types of capitals: natural capital; produced capital; human capital, a debate captured in terms of *'strong sustainability'* and *'weak sustainability'*.

Ecologically, strong sustainability models view natural capital as the fundamental layer on the top of which societies and economies are built. Due to its life supporting provisioning of natural capital, it cannot be substituted for with any other type of capital (for example, produced capital, human capital) in each period for intergenerational sustainability. Thus, under the strong sustainability development paradigm, all development policies should focus on developing human capital and produced capital, independently from natural capital.

Whereas, weak sustainability focuses on the total wealth of nations estimated from the monetised aggregates of all types of capitals over the long-run. It suggests that as long as total wealth is maintained, or preferably increasing over time, a country is on a sustainable development path. The key condition for weak sustainability models given by Hartwick's 'rule of thumb' is that the depletion of natural capital can be compensated for with equivalent investment in produced capital and human capital. In future, higher production efficiencies from technological advancement (in produced capital) and rich human capital (skilled labour) will off-set any adverse environmental impacts.

Both of these approaches have been subject to criticism. For example, strong sustainability has been criticised for overlooking the resilience of natural capital and waste of unused natural capital through natural processes. Whereas, weak sustainability has been criticised for allowing infinite substitutability of natural capital with other types of capital. We argue, instead of adopting either of these extreme approaches, sustainability policies can be defined by adopting a balanced approach, where substitutability between various types of capitals is allowed for (as suggested in weak sustainability models) in order to build national wealth (in terms of all capitals) but – crucially – subject to CNC limits (to be consistent with strong sustainability conditions).

2.9 Future Directions

Sustainability is not a destination rather it is a process of continuous improvement. It cannot be confined to one single place in isolation neglecting the planet as a whole. Weak sustainability subject to CNC limits is the minimum SD criteria to meet for every part of the world to thrive as earthlings. In doing so, we need to broaden the focus of SD indicators to places at different scales – from regions, to countries, to continents (and oceans) and, ultimately, to the planet.

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Chapter 3: Sustainability and Wellbeing: A scientometric and bibliometric review of the literature

Abstract

Interdisciplinary research on measuring the progress towards Sustainability and Well-being (SaW) from different perspectives and in various contexts, has developed dramatically over recent decades. This growth in the literature has not only added an enormous number of dimensions to the SaW debate, but the sheer scale of the expansion has challenged researchers to be able to conduct a comprehensive analysis of the available SaW indicators. In this work, we have proposed a hybrid method comprised of sophisticated scientometric analysis to summarise scientific developments in the massive text corpus of the SaW literature in conjunction with a more traditional literature review to categorise the 'fuzzy' details that remain. Scientometric analysis highlights that the developed OECD countries play a vital role in the development and applications of SaW indicators and we describe key developments in this regard via a range of graphical approaches. Using an extensive collection of existing SaW indicators, the analysis is then summarised in a matrix of ranked indicators which serve as a powerful tool to compare, contrast, filter and select indicators for SaW assessment with minimum redundancies between indicators. The approach undertaken in this study is intended to be flexible and can be extended and applied to other fields of research.

Keywords: *Sustainability, well-being, indicators, bibliometrics, scientometrics,* literature analysis.

JEL classifications: Q32; Q57; Q50; I30; Y1.

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3.1 Introduction

The concepts and definitions of Sustainability and Well-being (SaW) are complex, inter-dependent and inter-disciplinary. One of the fundamental aims of sustainability studies, for example, is to highlight ways to increase or maintain intergenerational well-being, whereas, the literature on well-being revolves around physical limitations which might inhibit the achievement of the desired level of well-being. Despite these factors, researchers tend to study these subjects differently based on their professional affiliation, academic background, geographical location etc., (Brunn, 2014, Roberts et al., 2013). In addition, the growing inter-disciplinary literature in the field of SaW not only brings complex dimensions into the debate, but also poses a challenge in selecting which indicators should be used to quantify sustainable well-being comprehensively.

A variety of single and composite indicators have been applied to measure SaW in the literature ranging from simple indicators addressing one particular SaW dimension (e.g. literacy, mortality, income distribution, carbon emission etc.) to complex composite indicators (e.g. Human Development Index (HDI), Ecological Footprint (EF), Genuine Savings (GS), Genuine Progress Indicator (GPI)), a range of life cycle methods (e.g. Life Cycle Assessment (LCA), Life Cycle Costing (LCC) etc.) and so on. Notwithstanding the availability of numerous SaW indicators, there seems to be no consensus regarding the 'best' approach to sufficiently quantify the progress towards multi-dimensional SaW (Wilson, Tyedmers, & Pelot, 2007).

According to Michalos (1997), the success of a particular comprehensive system of indicators to measure SaW is limited by the researcher's subjective point of view about the consumption of capital stocks (e.g. natural capital, produced capital, human capital, social capital etc.) in order to satisfy present needs and the preservation of these stocks to meet future needs. At a conceptual level, this is the choice between 'weak sustainability' or 'strong sustainability' (Pezzey & Toman, 2002) a classic dispute between (Georgescu-Roegen, 1971) and (Solow, 1974). If that is the case, it might be better for researchers to abandon efforts to develop a single comprehensive, utopian system-based index on the agreed list of important goals, indicators, and monitoring methods, to implement sustainable well-being. Rather they should move forward with a set of indicators which sufficiently cover the required details of SaW for a given group of people, place, country or region over a given timeframe to tell a coherent story.

Furthermore, the selection of indicators on which to conduct SaW related studies is a critical stage, where researchers need to consider issues related to the coverage, comparability and redundancy in a given set of indicators. The Australian National Development Index, for example, is an indicator for a specific country and may not be applicable to other parts of the world without modifications. Similarly, several indicators are specific to certain age groups, ethnicity, religion, etc. and therefore are not universally applicable. On the other hand, many of these indicators are constructed on similar determinants with slight differences and therefore are highly correlated and convey similar messages with very little or no new information. Over time, one indicator may become redundant or irrelevant in the presence of a new indicator. For example, a number of studies using more than one SaW indicator to conduct comparisons at local, national and regional level have shown, in most cases with very few exceptions, that the best performers with respect to one particular SaW indicator are also high performers with respect to other SaW indicators (Bradshaw, Giam, & Sodhi, 2010, Dietz, Rosa, & York, 2009, Engelbrecht, 2009, K. W. Knight & Rosa, 2011, Moran, Wackernagel, Kitzes, Goldfinger, & Boutaud, 2008). To be more specific, a high-income country would also rank high on the HDI in general, therefore, using income level alone may be redundant in the presence of HDI as income is built-in to the HDI measure itself.

Scholars have adopted different approaches to conduct surveys of SaW indicators, which can be broadly categorised under two major classes. In the first category, commonly used methods are: i) ranked on the basis of a descriptive comparison of popular indicators to choose 'preferred' measures based on logical reasoning, for example, (Alcorn, 2010, Babarenda Gamage, 2011, Michalos, 1997, Mitchell, May, & McDonald, 1995, Rice & Rochet, 2005, Wilson et al., 2007)) applied Max-Neef's matrix of human needs[1] to benchmark SaW indicators. Similarly, another group of scholars including (Costanza et al., 2007, Dodds, 1997, Jackson, Jager, & Stagl, 2004, Jackson & Marks, 1999, Roberts et al., 2013, 2015)) applied Maslow's hierarchical needs framework[2] (Maslow, Frager, Fadiman, McReynolds, & Cox, 1970) for generating or selecting a set of SaW indicators.

In the second category of papers, scientific developments are tracked using 'big data' methods (e.g. scientometrics[3], bibliometrics[4]) applied to identify SaW indicators from a larger domain. In this approach, the information is characterised via the interpretation of visual diagrams generated from the analysis of a large corpus of text documents (Börner, Chen, & Boyack, 2003, Fortuna, Grobelnik, & Mladenic, 2005, Paré, Trudel, Jaana, & Kitsiou, 2015). Such methods are gaining considerable attention from scholars in both the natural and social sciences. For example, (Waaijer & Palmblad, 2015) studied the developments in the field of analytical chemistry over 80 years, whereas (Brunn, 2014) studies knowledge gaps and boundaries in sustainability in the text corpus of 64 academic journals.

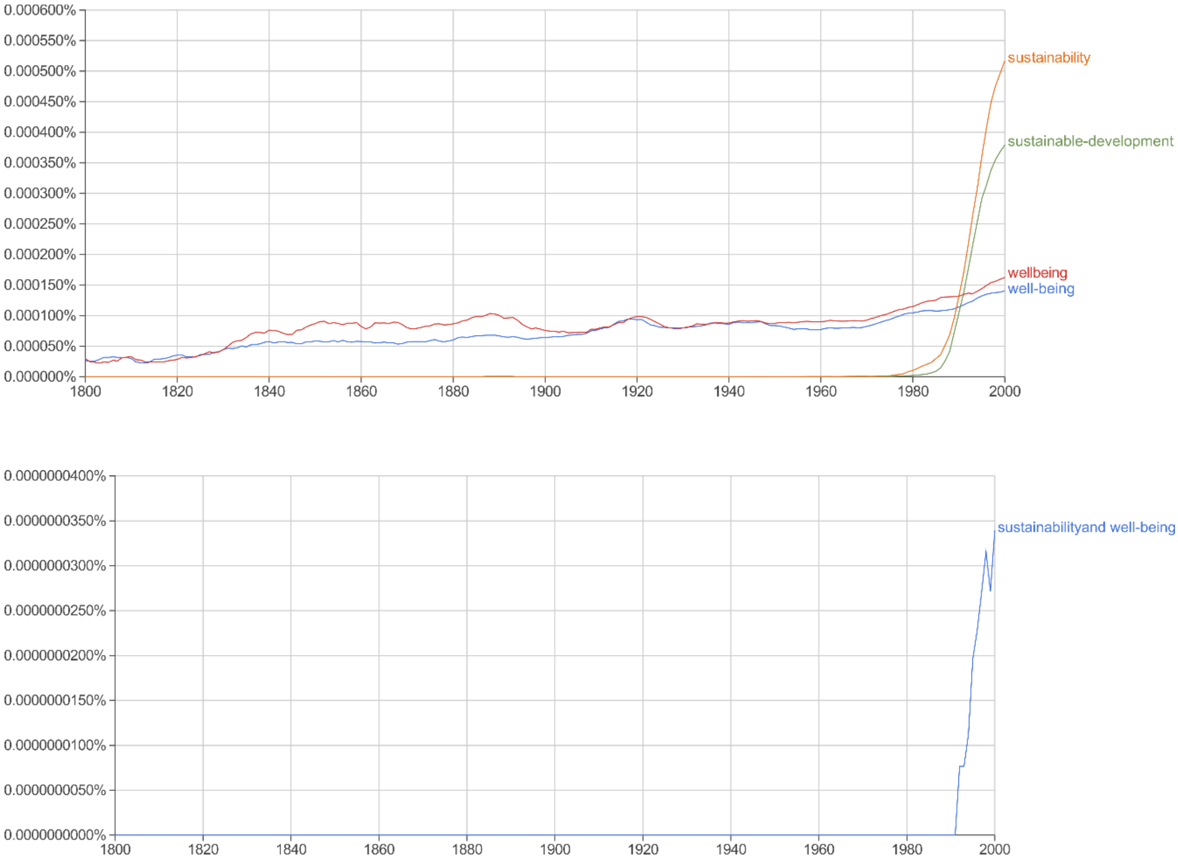
In this paper, we have developed and applied a hybrid approach to identify a set of indicators for SaW assessment. This approach harnesses modern computing power to analyse the 'big data' elements of text documents to identify underlying patterns, which is then complemented by a more traditional literature review to extract sensible information from these patterns using logical reasoning. In the example presented in this paper, methods and indicators are identified to combine social, economic and environmental dimensions of sustainability with human well-being on the inter-temporal scale to tell a coherent story of sustainable well-being over the long-run. In our ranked matrix, we found GS and EF are vital SaW indicators in this regard.

The rest of the paper is structured as follows: Section 2 describes the data and data collection methods. In-depth scientometric and bibliometric analysis is presented in section 3. Section 4 draws conclusions and makes recommendations. Section 5 summarises key findings and lays out a generic template to apply the scientometric framework to other datasets.

3.2 Data Collection

Public interest in both sustainability and well-being is at its historical peak. Figure 1 plots references to the words: "sustainability", "sustainable development", "wellbeing", "well-being", and "sustainability and well-being" in the corpus of Google Books published between 1800 and 2000. We observe that well-being has a long history in the literature extending over 200 years. This is because human well-being has been the prime focus of research under several disciplines (such as health, medicine, psychology) whereas sustainability and/or sustainable development is a relatively new concept emerging in the late 1980s around the time of the Brundtland Commission report in 1987 (Bruntland & others, 1987). SaW as a combined concept, therefore, is the newest discipline with a very brief history starting in the early 1990 as shown in the bottom part of Figure 1. This is the time when World Bank's Genuine Savings or adjusted net savings emerged as a long-term sustainability indicator followed by other similar SaW indicators including comprehensive wealth, well-being index (WI), HDI, EF etc. (Wilson et al., 2007). A enormous influx of scholarly interest is observed recently in this area.

Figure 1: Incidence of references to SaW in Google Books 1800 – 2000



The graphs are derived using the Google Books Ngram Viewer (Michel et al., 2011). The corpus of words and phrases was formed from 5.2 million books (a subset of all Google Books) and holds over 500 billion words. The graph shows a moving average of the incidence of a word, normalised by the total number of words in the books published in a particular year. For discussion of the Viewer and its strengths and weaknesses (including possible biases) see (Ravallion, 2011).

To investigate historical developments in the field of SaW comprehensively, we have undertaken a data intensive literature review. In contrast to traditional literature review methods which are generally *ad hoc*, our approach can handle a massive amount of literature to explain scientific developments and identify latent patterns. One of the key reasons to apply scientometrics for literature analysis is that it minimises the risk of missing important information from any paper which could be missed by using traditional literature review methods because of time and resource constraints.

We used the ISI Web of Science Core Collection database web interface to download bibliographic data of all publications (available to the access date) related to measuring SaW over the period of 22 years from 1992 to 2014. This database maintains up-to-date research output information, which is commonly used in scientometric studies. We found 638 publications during this period, categorised in Table 1, (data were collected on the 24th February 2015).

To select the set of papers, we started by searching for the following set of keywords (‘sustainability OR sustainable development’) AND (‘well-being OR wellbeing’) AND (‘indicator OR measure OR evaluate OR estimate OR assess OR quantify OR index OR empirical’). In order to get the maximum number of relevant papers, OR joins are used between keywords. Furthermore, different possible combinations of keywords were also searched to further sense check the results to avoid unnecessary exclusions of important papers.

Table 1: Documents by type included in the collection

Document Types	**Records**
ARTICLE	548
BOOK CHAPTER	50
OTHERS	40

Each paper in the collection was carefully assessed to allocate Sustainability (S), Well-being (W) or both Sustainability and well-being (SaW) categories to the paper. A count of the papers by SaW category is summarised in Table 2.

Table 2: Documents by SaW category

SaW category	**Count**
Sustainability (S)	254
Well-being (W)	213
SaW	171

This paper presents a survey of SaW literature in two key parts: i) a number of modern scientometric methods are applied to summarise core characteristics of the

SaW literature and historical developments in this field from the corpus of 638 papers. One of the key strengths of this paper is that the results presented in the scientometric analysis part are reproducible given that the same steps are followed; ii) The collection of indicators used in the given set of documents was manually extracted and assigned a ranking score based on the number of citations received by the paper they belong to. After that, ranked indicators were arranged in a matrix (Table 4) in such a way that composite indicators are placed in the first row across the columns and single indicators are positioned in the first column across rows (leaving the first cell of the matrix blank). Some of the individual SaW indicators are used to construct a composite indicator, which we mark in the corresponding cells. In this way, the resultant matrix presents a systematic summary of available indicators for the assessment. The matrix enables a researcher to compare, contrast, filter and select from a huge list of potential indicators on a ranked scale with much less effort. The approach taken in this study could be applied to describe the structure and developments in other fields of science and its relationships with the other disciplines.

3.3 Scientometric analysis

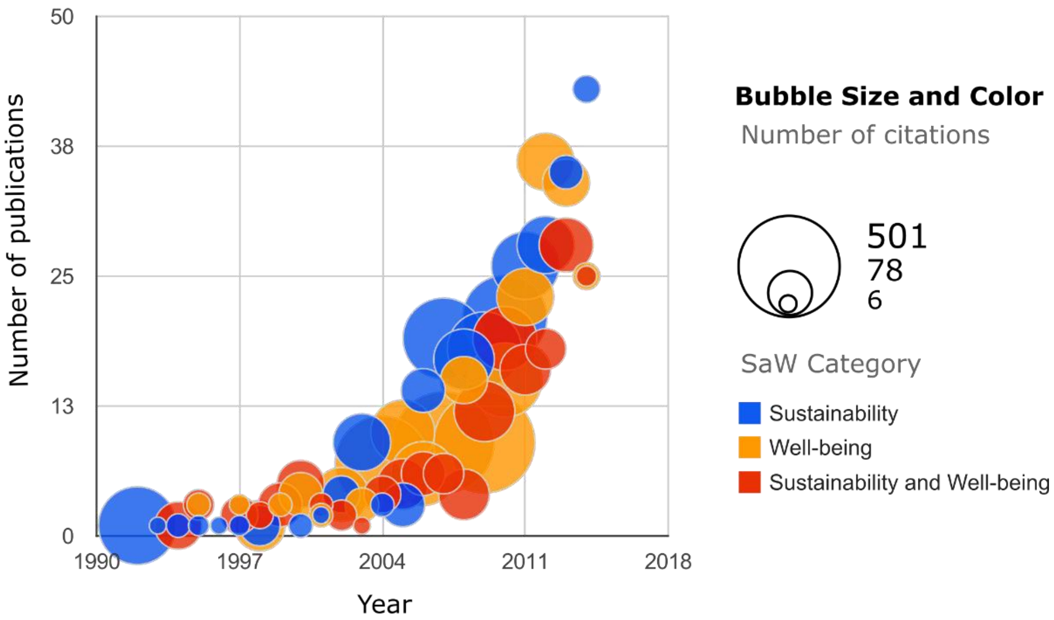
In this section, we have applied a number of scientometric tools to develop inter-linked network visualisations with an aim to explain the dynamics of research related to measuring SaW. Outcomes of this exercise include the identification of publications, people, places, communities, organisations and networks leading the development of various methods to quantify SaW in various settings in order to identify seminal studies and summarise the evolution of SaW measures overtime. A complete list of tools applied to conduct scientometric analysis is provided in the appendix.

3.3.1 Trends in publications

The number of publications per year is a commonly used indicator of research activity in a given field and the number of citations is a frequently used measure of the 'quality' of publications in many scientometric studies (Ding, Rousseau, & Wolfram, 2014). To put quantity versus quality into the perspective for our collection of papers, historical trends of publications per year and their number of citations are summarised in Figure 2 by SaW category.

In general terms, the number of publications has been increasing every year in all three categories, which shows the growing research interest in these fields. The first paper in our ‘sustainability’ category was published in 1992 and this number peaked at 46 publications per year in 2014. In the case of our ‘well-being’ category, the first paper appeared in 1993 and this number reached its peak at 36 papers per year in 2012. Research related to both sustainability and well-being (SaW) in our collection of 638 papers begins in 1994 and peaked at 27 papers per year in 2013.

Figure 2: Publications by year, by number of citations and by SaW category



However, trends in the number of citations for a given number of publications in a year exhibit much more variability for each SaW category. A small number of publications in a year with a very high number of citations indicates a higher ‘citations per publication’ which is often regarded as a measure that reflects high ‘quality’ of the work. For example, in the ‘sustainability’ category, these studies include heavily cited work (given by the size of bubbles in Figure 2) by (Carpenter et al., 2009, Chiesura, 2004, Costanza & Daly, 1992, Maller, Townsend, Pryor, Brown, & St Leger, 2006, Newton, Côté, Pilling, Jennings, & Dulvy, 2007). There is a higher number of publications with a small number of citations per publication, representing either relatively ‘low quality’ publications or studies with limited scope. For instance, there are 43 publications related to sustainability in year 2014, only 10 of which were cited 27 times by others. The remaining 33 had not been cited by anyone by the day data were collected (See here the concept of PI-BETA, or 'Papers Ignored By Even The Author' in Chang, McAleer, & Oxley (2011)). Such publications mainly include studies related to the assessments of certain dimensions of SaW for certain groups of people in a specific region, which may not attract the attention of the global community of scholars, for example work by (Barrera-Roldán et al., 2003, Nogueira, Santana, & Santos, 2006). The other important reason for low citations relates to recent studies which might become important in the future but that are yet to be frequently citated i.e., (Akenji & Bengtsson, 2014, K. Knight, 2014).

3.3.2 Bibliometric Networks in SaW literature

Bibliometric networks, often referred to as "science maps", have received considerable attention since the origins of bibliometric studies within and outside the scientometric research communities. Visualization of large networks has turned out to be a successful approach to analyse a wide range of networks e.g. relationships between publications, authors, co-authors and publishers, network of co-occurring keywords etc (Börner et al., 2003, Börner, Sanyal, & Vespignani, 2007, N. J. van Eck & Waltman, 2014). This section offers an overview of key developments in the SaW literature with the help of several types of bibliometric networks.

3.3.2.1 Topical and geographical maps

A **topic** is a set of co-occurring words in a text corpus (e.g. "sustainable development"), which can be aggregated over a number of research attributes such as journals names, scientific disciplines, or institutions. Topical maps are powerful tools to study the current structure of science for a given set of papers (Börner & Scharnhorst, 2009, Skupin, Biberstine, & Börner, 2013)[5]. Topical analysis extracts the set of unique words with their frequencies from a collection of documents. Data pre-processing (e.g. removing stop words[6], stemming[7] etc.) is then applied. Word co-occurrence analysis computes the number of times two words are used in the title, abstract, keywords or full document body within and across a given set of documents. Finally, the structure of science can be summarised by topic. SaW is an interdisciplinary subject and so is its measurement. Figure 3 summarises how papers on measuring SaW are topically related on the UCSD Basemap of Science (Börner et al., 2003, Börner & Scharnhorst, 2009).

The UCSD map of Science is a network diagram of 554 subdisciplines of science grouped into 13 overarching disciplines and their relationships to one another. This visualization represents the result of mapping a dataset's journals to the underlying sub-discipline those journals contain. Mapped subdisciplines are shown with size relative to the number matching journals and colour from the discipline. Each **node** on the map represents a set of journals, and papers are overlaid based on similar journal names. The size of the node shows the number of papers per node. Figure 3 maps count of papers from 261 journals out of 393 journals categorised to 207 subdisciplines and 13 disciplines. The remaining 132 journals fall under the unclassified category.

Most of the work related to the measurement of SaW comes from social science journals, biology and health, and a small number of papers belong to natural science disciplines i.e. maths, physics, chemistry earth sciences etc. (Please see the Appendix for counts of papers by journal name.) This clearly shows the degree of interdisciplinarity of SaW.

Another way to detect similarities between a given set of papers is to use multi-dimensional scaling visuals of their source journals using a computer program called VOSviewer introduced by (N. van Eck & Waltman, 2007, 2010) applied in recent SaW studies by (Certomà, Corsini, & Rizzi, 2014, Hellsten & Leydesdorff, 2015, Holmberg & Hellsten, 2015, Rosa, Spyra, & Inostroza, 2015). Figure 4 summarises the clustered network of journals for our dataset calculated based on journal co-citation data. In these visuals, the distance between the objects reflects the extent of their similarity and the colour of nodes indicate the cluster to which a journal is assigned by the clustering algorithm, and the text label on the nodes is the short name of the source journals (please see (N. van Eck & Waltman, 2010) for technical details of the VOSviewer program and the mathematical algorithms it applies to cluster the data). VOSviewer results are consistent with the map of science results that journals relevant to environmental sciences (e.g. ecological economics, social indicators research, ecological indicators, world development) and social sciences (sustainability science, energy policy, journal of cleaner production, journal of environmental management) are the key sources of SaW measurement studies. There are a significant number of contributions from journals of the natural sciences (e.g. journal of remote sensing and applied geography). The map also identifies the group of studies from the medical sciences, which show relatively weak degree proximity with the other clusters, and are shown by the green clusters.

Figure 3: Topical map

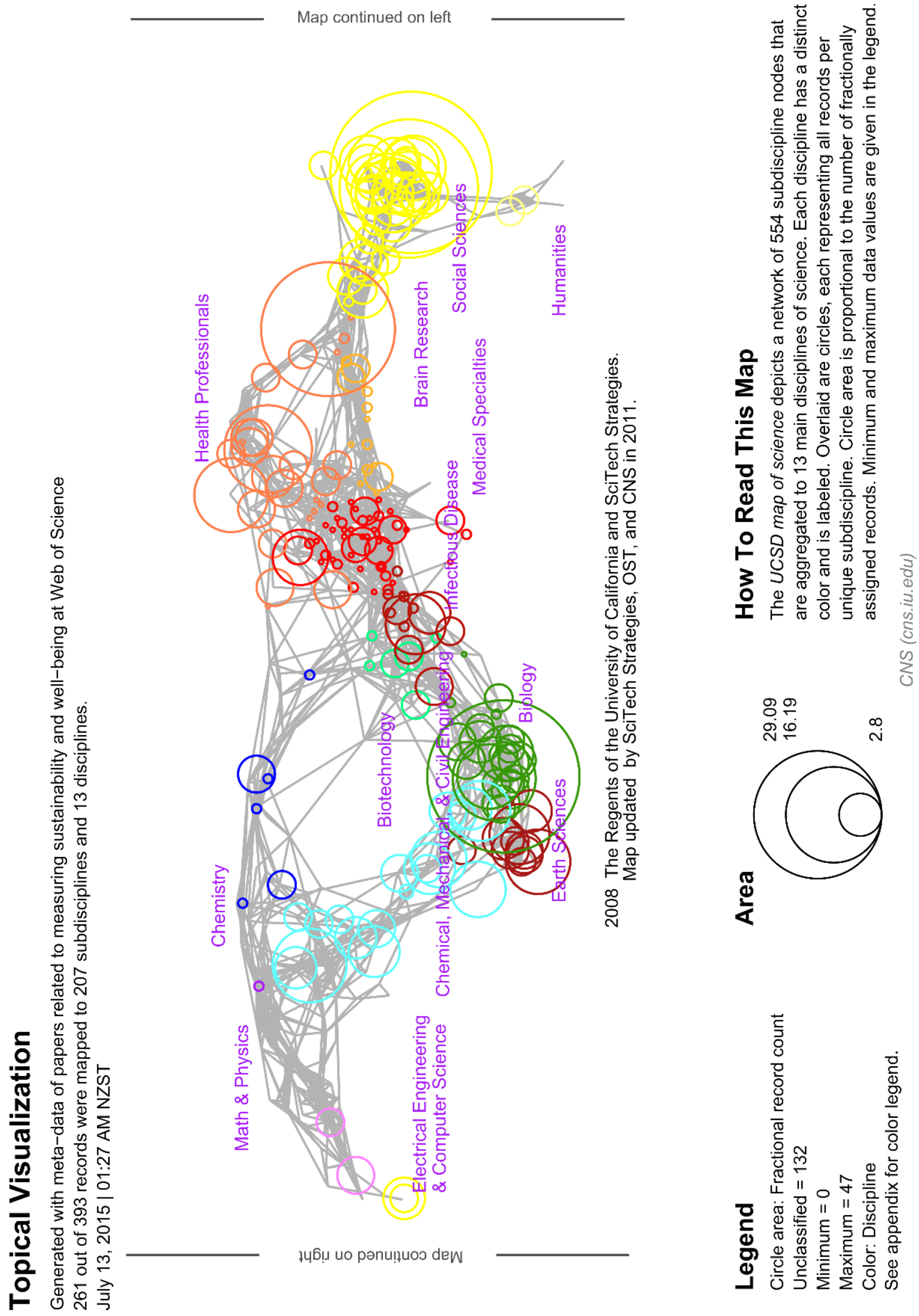
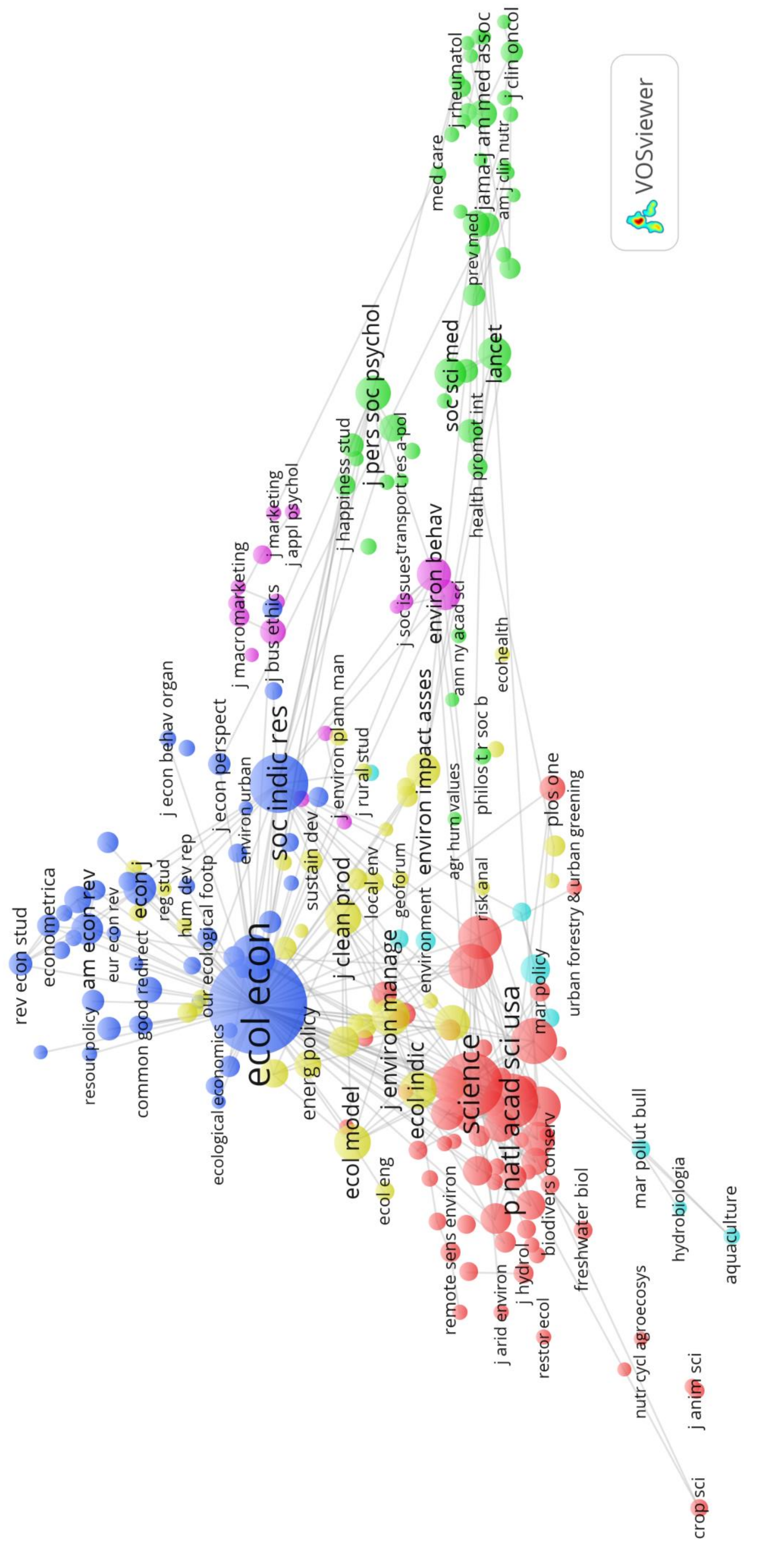


Figure 4: Co-citation source map



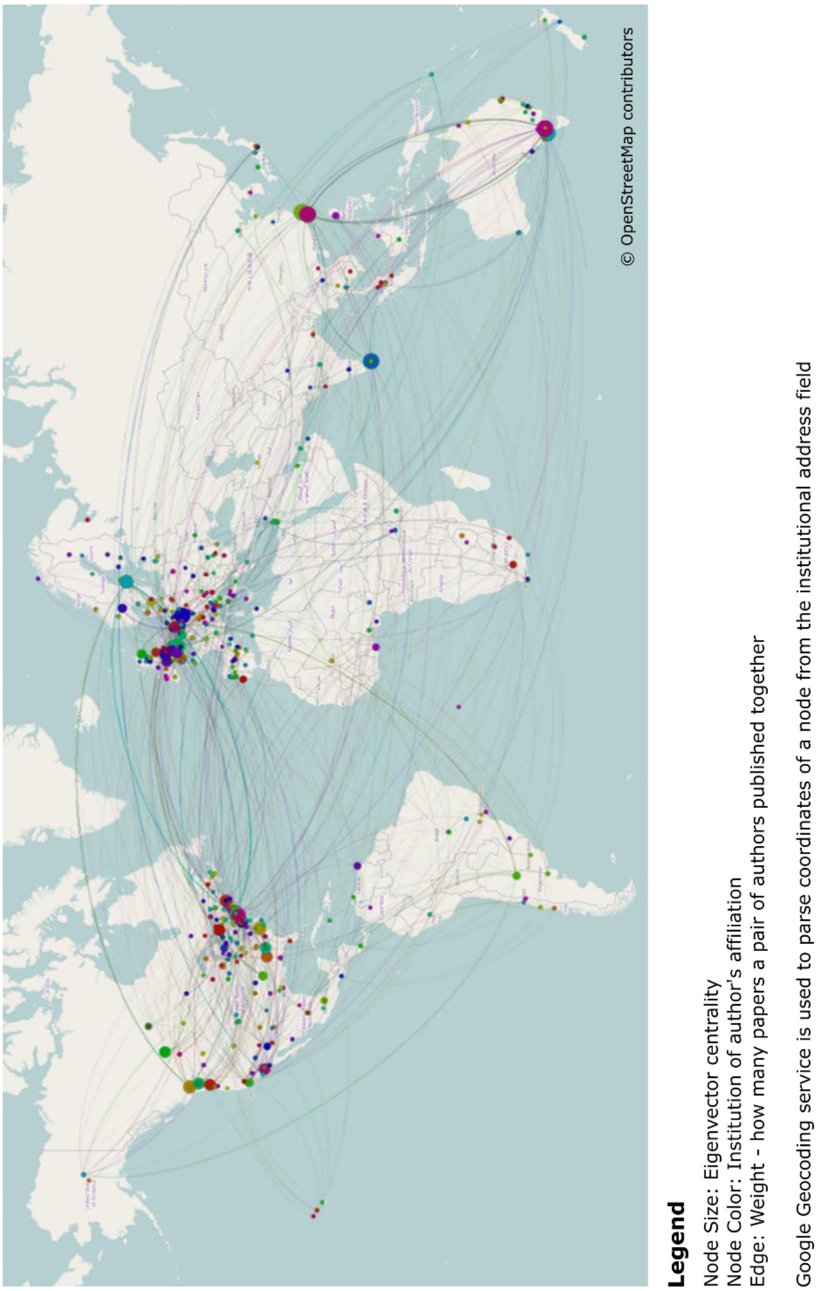
An alternative perspective on SaW knowledge is obtained by looking at the home country of the disciplinary and inter-disciplinary authors of the SaW research. Figure 5 is a directed geo-network map, which shows the country of the first author of a publication (represented by blue nodes) and the country of its publisher (represented by brown nodes)[8]. Map edges run from authors to the publishers SaW category is shown by the colour of the edges. The United States and Europe, not unexpectedly, are the home to most of the SaW researchers and scholars. With just a few exceptions, most of SaW research comes from OECD countries. 30% of SaW papers in our collection were written by main authors from the United States, 63% by people from OECD countries and only 7% from the rest of the world. At a regional level, there is no contribution from North Africa on SaW research since 1992 in our set of papers analysed. On the other hand, publishers of over 98% of the papers are from developed countries with just a few exceptions from Brazil, China and India. Geography of the publisher indicates that most of the publishers are from America and Europe drawn from the ISI Web of Science data (see http://wokinfo.com/mbl/publishers/ for details).

Figure 5: Author & publisher map by SaW category

3.3.2.2 Co-authorships and collaborations

Networks of scientific collaboration have been systematically studied since 1960 by researchers from various disciplinary backgrounds. Since then, the complex phenomenon of scientific collaboration networks has been explored within different approaches (Mali, Kronegger, Doreian, & Ferligoj, 2012). In general, it is agreed that institutional, national and global research collaborations are directly linked with the number of citations for a publication as well as collaborations playing a vital role in leading research agendas (Ding et al., 2014, Hassan & Haddawy, 2015, Hood & Wilson, 2003, Sooryamoorthy, 2009). In SaW studies, the importance of research synergies and collaborations are observed (Figure 6) and are well-acknowledged by a number of studies including: (Davidson, Trudeau, Ockene, Orleans, & Kaplan, 2004, Galloway, Bell, Hamilton, & Scullion, 2006, Goldkind, Pardasani, & Marmo, 2013, Waldron, 2010)[9]. As expected, the majority of SaW research collaborations are evident in developed countries with some contributions from South Asia and South Africa.

Figure 6: Co-author map



Bibliometric networks discussed so far reflect the current structure of science. Figure 7 summarises how collaborations have evolved in the field of SaW over time by splitting the co-authorship network into four sub-networks each with a five-year window. The co-authorship network includes the top 200 nodes by citation in each window. There are a small number of collaboration by only two or three people between 1992 and 1997. In the following year, we note a large increase in collaborations as well as an increase in the size of the networks. These small sub-networks show that certain groups of scholars are addressing SaW research from particular dimensions in each network. To illustrate this argument, we applied the Blondel community detection algorithm (Blondel, Guillaume, Lambiotte, & Lefebvre, 2008) to extract hierarchical clusters of the network. This algorithm is widely applied to cluster large networks into smaller groups. The resulting undirected network of co-authors from the top 200 frequently cited publications in our dataset are presented in a circular hierarchy of clusters network given in Figure 8[10].

Community detection network diagrams identify disciplinary and inter-disciplinary groups of authors. Author names are plotted in a circle and connecting lines represent co-author links. Two of the researchers share a combined network, while the others are at the centres of unconnected networks. Connectedness of authors is given by the weight of edges; the size of nodes indicates the number of co-authored work; number of citations are given by the colour of each node, and each mark on the ring indicates a community to the author name who belongs to that community.

Figure 7: Evolving co-authorship network in SaW

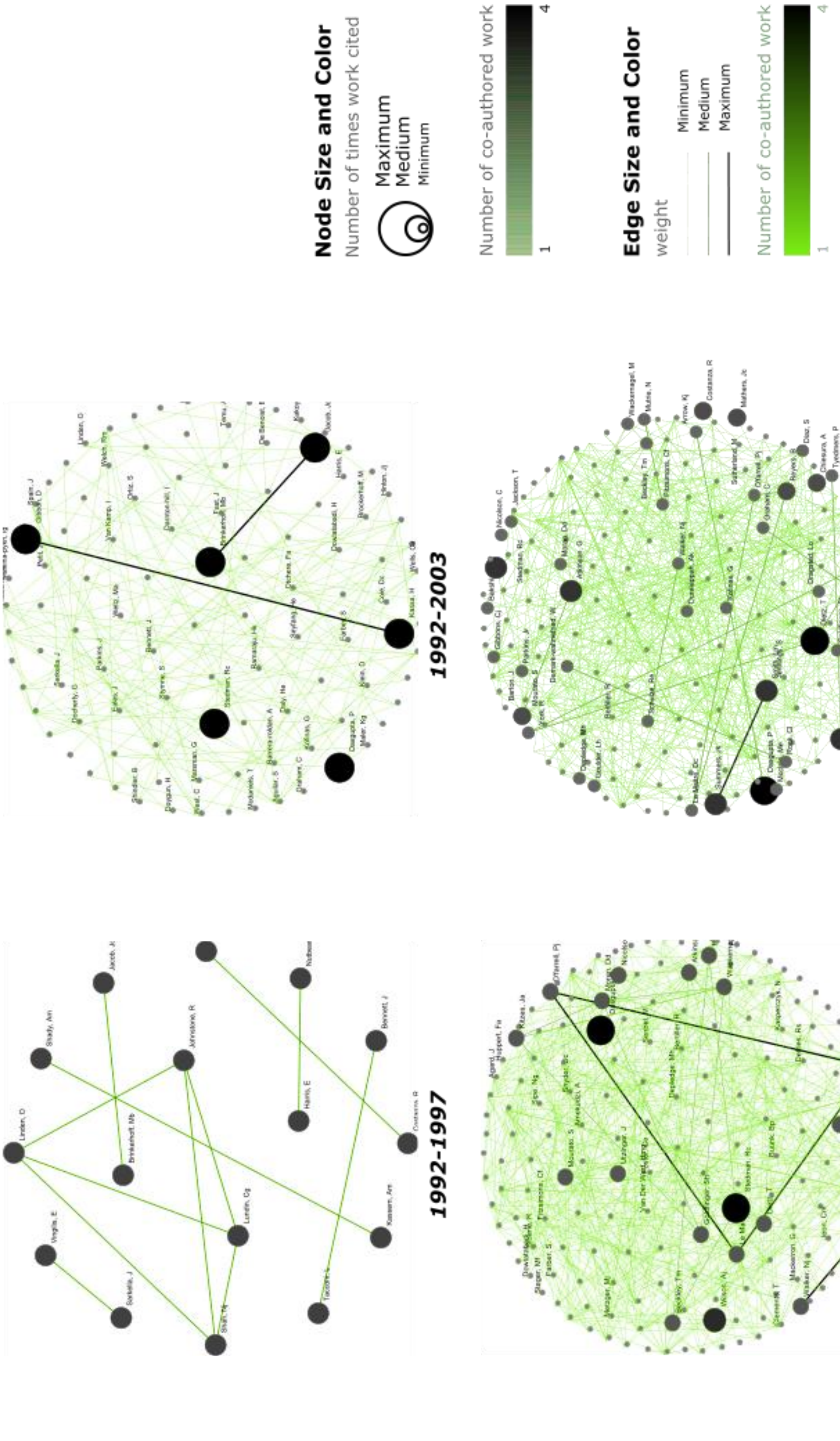
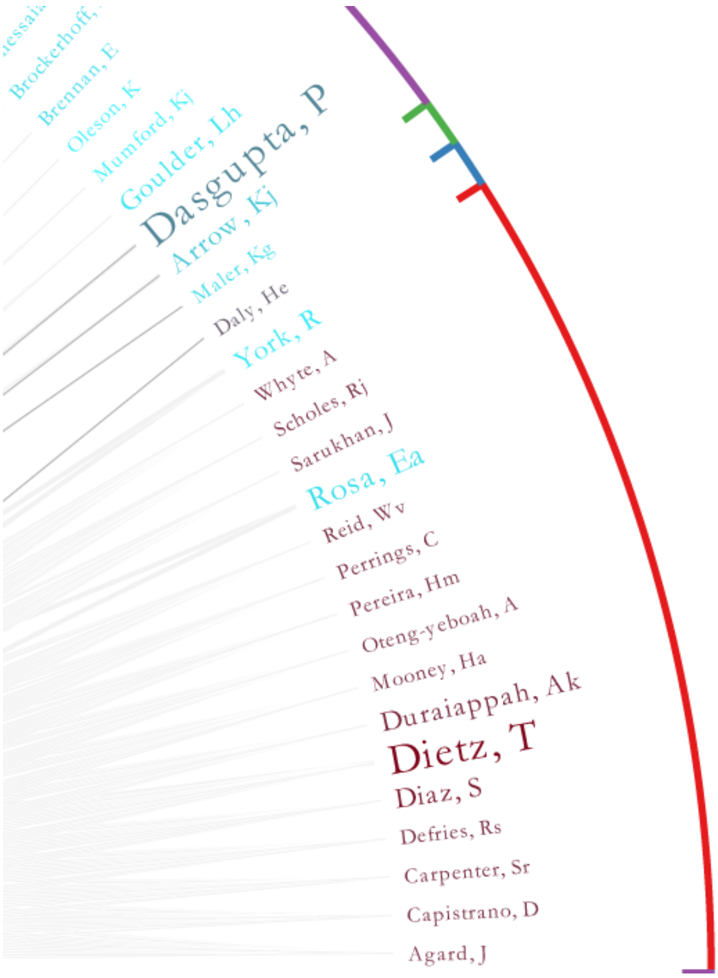


Figure 8: Community detection within co-authorship networks of SaW



This is a zoomed slice of the full diagram to make it readable on the paper version. Please see Figure 8 full version in the appendix or refer to the online version.

By looking at the research work done by people within a community, we found a clear split of disciplines among individuals and groups. For example, one of the notable communities include the authors Dietz, Diaz, Defries, Carpenter, Capistrano, Agard, Mooney, Oteng-yeboah, Pereira, Perrings, Reid, Rosa, Scholes, Whyte and York who have been addressing SaW from a natural capital and ecosystem services perspective. Similarly, another group, which includes Dasgupta, Arrow, Maler, Goulder, Mumford and Oleson have studied SaW with a dominant component of natural resource accounting, measurement of national wealth and consumption levels. There are a large number of inter-disciplinary authors in the group comprising Atkinson, Gibbons, Mourato, Gardner, Grenyer and others who have applied multiple/composite indicators to measure SaW. To bring further granularity to the bibliometric analysis, co-authorship networks are often complemented by co-citation analysis (Börner et al., 2003, Ding et al., 2014, N. J. van Eck & Waltman, 2014) given under the following heading.

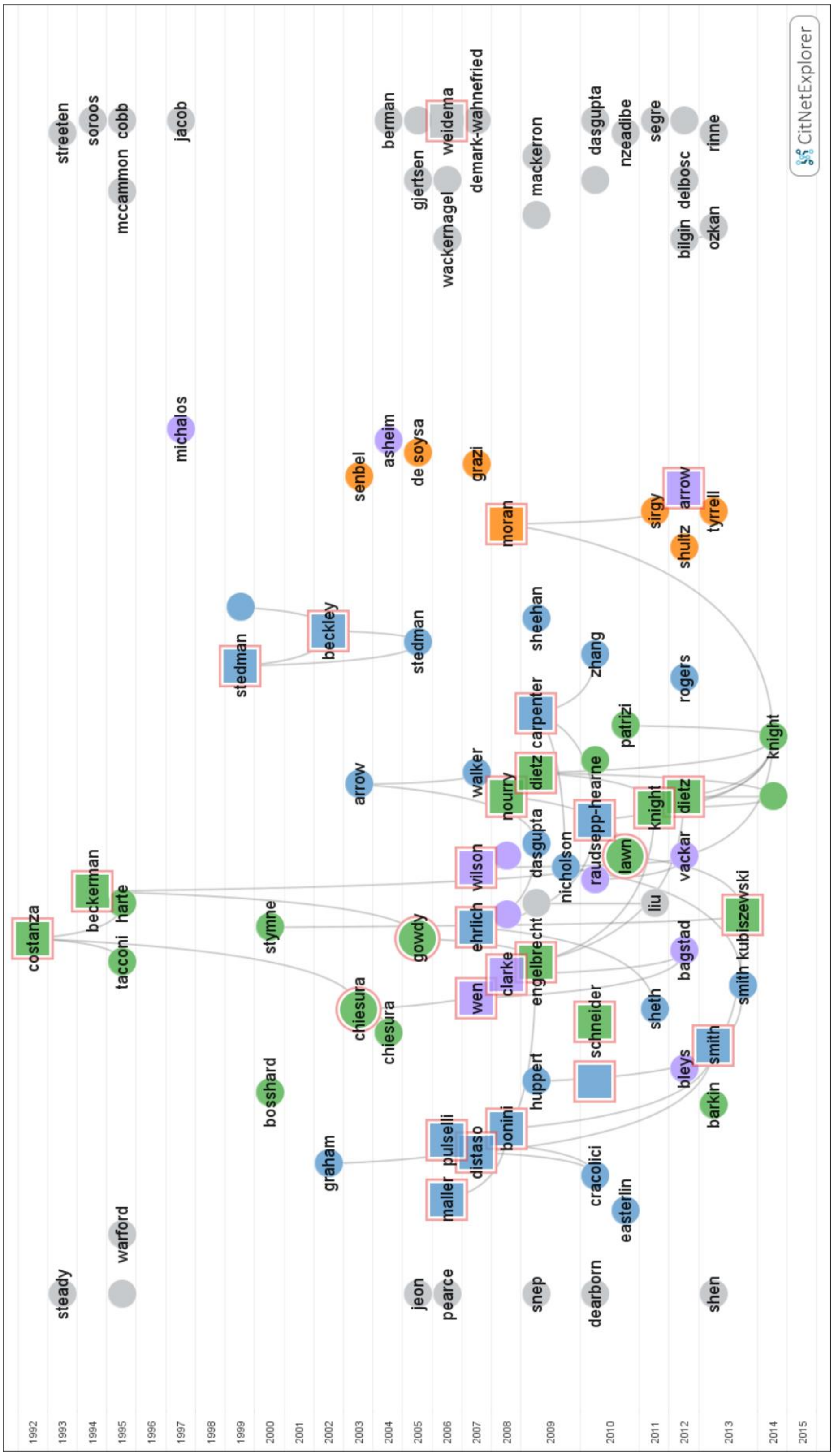
3.3.2.3 Evolution of research related to measuring SaW

Directed citation networks are commonly used methods to identify scientific advances in a field (Adam, 2002, Hassan & Haddawy, 2015). We used CiteNet Explorer, which is a tool for analysing and visualising networks of scientific publications (N. J. van Eck & Waltman, 2014). Figure 9 shows the clustered network of 100 frequently cited publications in the collection (where a cluster is a set of strongly connected publications in terms of citation relations). Core publications, with a relatively high number of citations within clusters, are marked with a red outline around the node.

An overview of this network makes clear that the dominant green cluster consists of work related to environmental dimensions of SaW and its variants. It is based on the seminal work of (Costanza & Daly, 1992) in which they study the role of ecosystem services to achieve sustainable development and established minimum levels of natural capital to be maintained for sustainable development, using natural resource accounting methods and, (Beckerman, 1994) where the philosophy of sustainable development and its measurement is reviewed. In the subsequent studies, their work was translated into the notion of strong sustainability as an approach to sustain well-being. For details see (Chiesura & de Groot, 2003, Engelbrecht, 2009, Gowdy, 2005).

Similarly, core publications in the blue cluster including (Carpenter et al., 2009, Maller et al., 2006, Stedman, 1999) focus mainly on social, cultural and economic dimensions of the SaW literature. The purple cluster combines studies relating to economic and ecological indicators, which includes the core publications of (Arrow, Dasgupta, Goulder, Mumford, & Oleson, 2012, Wilson et al., 2007). Finally, the orange cluster brings together papers with multiple SaW indicators, for example, the work of (Moran et al., 2008) in which they applied Environmental Footprint (EF) together with the Human Development Index (HDI) to measure and compare the status of sustainable development across 93 countries. The remaining grey nodes do not have direct citation relationship with other publications in the subset of data used to develop this network. Inter-linkages of SaW publications are indicated by edges connecting two separate clusters such as the connection between (Moran et al., 2008) and (K. Knight, 2014). The top 25 publications identified in this network are summarised in Table 6 in the Appendix.

Figure 9: Citation relationship between top 100 papers



NOTES:
Each node represents a paper
Node label is the last name of the first author
Edges represent citation relations

Horizontal node position: relationship between publications
Vertical node position: publications by year
Node color: clusters (minimum cluster size 10)

Squared pulication are heavily cited by other papers in the collection.

3.3.2.4 Indicators of SaW

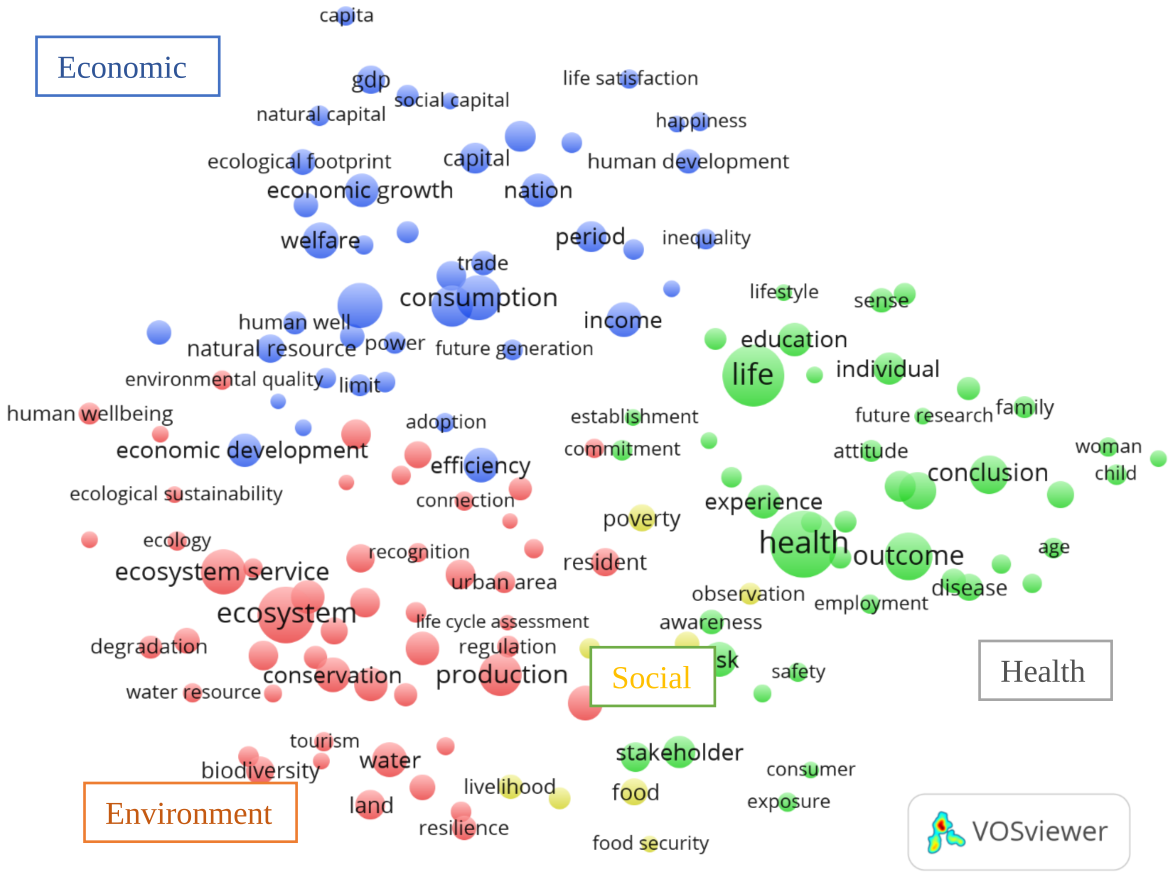
We applied bibliometric keyword analysis methods to automatically identify indicators that quantify SaW. This methodology has been adopted by several recent studies to auto-detect the dimensions, developments and indicators within and across scientific fields from the large corpus of papers. For example, (Waaijer & Palmblad, 2015) applied bibliometric mapping to study the developments in the field of analytical chemistry over a period of 8 decades, (Rosa et al., 2015) used this method to summarise indicators of cultural ecosystem services, (Certomà et al., 2014) to study the focal points of urban sustainability and (Holmberg & Hellsten, 2015) to identify the gender differences in climate change communication.

We adopted a three-step approach to cover SaW indicators in the given dataset.

1. Bibliometric analysis is applied to extract SaW dimensions from frequently co-occurring key-terms
2. Indicators to quantify SaW dimensions are manually extracted
3. Dots are joined by summarising and ranking indicators into a matrix of SaW indicators

We scanned 638 SaW publications in the dataset using VOSViewer (N. van Eck & Waltman, 2007, 2010) to generate the term map (presented as Figure 10) showing the most important terms in the titles and abstracts of publications and the distribution of co-citations in the field of SaW. The key-term map provides a visual representation of the relationship between frequently co-occurring terms (at least ten times in the title, abstract and keywords fields) treated by a natural language processing algorithm to exclude verbs, adverbs, adjectives, conjunctions, etc. The size of the nodes denotes the frequency of a term; its proximity with other terms indicates the degree of relatedness with other terms and node colour represents the cluster to which a term belongs.

Figure 10: Key-term map



Results from the analysis with VOSviewer divides the key-terms into four clusters which can be categorised under economic, environmental, health and social dimensions of SaW. These dimensions highlight what is commonly measured in SaW papers, for example, the majority of SaW papers addressing an economic dimension deal with income, consumption, production, efficiency, capital etc. A full list of SaW indicators extracted from papers in the dataset is given in Table 7 in the Appendix. It is important to note that a number of SaW studies have used more than one indicator to quantify from the desired perspective. For instance, (Wilson et al., 2007) used EF, SB, ESI, WI, HDI and GDP to compare the state of SaW for 180 countries, (Dietz et al., 2009) used Natural Capital, Life Expectancy, Human capital, and EF to study SaW of 135 countries and (Nourry, 2008) studies the SaW of France using 8 different indicators i.e. Green national net product, GS, EF, ISEW, GPI, Pollution-sensitive HDI, Sustainable HDI and French Dashboard on Sustainable Development. A detailed list of indicators used, together with other indicators, is given in Table 8 in the Appendix by the number of citations of the publications to which they belong. A summary of SaW indicators used in conjunction with other SaW indicators are summarised in Table 3. HDI is the most commonly studied indicator in combination with other SaW indicator(s) such as EF, GDP, GS etc. follow by EF itself which is studied with other indications such as EWB, ESI, GPI etc.

Table 3: Summary of SaW indicators used with other indicator

HDI	**EF**	**Life expectancy**	**ESI**
EF	HDI	Natural capital	Building design
Access to Sanitation	Biocapacity	Human capital	DMC
Age	DMC	HDI	EF
Cardinal Green Index (CGI)	Ecosystem health assessment	Ordinal Green Index (OGI)	EFCO2
Comprehensive wealth	Ecosystem well-being index	Cardinal Green Index (CGI)	Energy efficiency
Consumption	EIOA	GDP	EWB
Country of birth	Emergy	Human Poverty Index (HPI)	GBL
DMC (direct material consumption)	Environmental efficiency of well-being (EWEB)	Underweight Children	GDP
Education	Environmental health	Access to Sanitation	Happiness Index
EFCO2	ESI	Enrolment Ratio	HDI
Enrolment Ratio	EWB	Consumption	QOL
Ethnicity	French Dashboard on Sustainable Development	Gini Index	SB
EWB	GBL	Crime rate	Thermal Comfort
French Dashboard on Sustainable Development	GDP	CO2 emission	WB
GBL	GPI	Water pollution	WI
GDP	Green national net product	Unemployment	**Happiness index**
Gender	Green net regional product	Expenditure on R&D	DMC
GPI	GS	Energy consumption	EF
Green national net product	Happiness Index	Renewable energy	EFCO2
GS	Human capital	EF	ESI
Happiness Index	Information availability	**GS**	EWB
Health	ISEW	EF	GBL
Household size	LCA	FDI	GDP
Human Poverty Index (HPI)	Life expectancy	French Dashboard on Sustainable Development	GS
Income	Life satisfaction	GPI	HDI
ISEW	MFA	Green national net product	Life satisfaction
Life expectancy	Natural capital	Happiness index	Natural capital
Living with	Population growth	Index of economic freedom	QOL
Locality	QOL	ISEW	WB
Location	SB	Life satisfaction	**Natural capital**
Ordinal Green Index (OGI)	Social welfare	Natural capital	Built capital
Pollution-sensitive HDI	WB	Natural resource accounting	Comprehensive wealth
Postcode. Country	WI	Pollution-sensitive HDI	Consumption
QOL		Sustainable HDI	EF
Relationship	**Human Poverty Index (HPI)**	**Natural capital**	GS
Safety	HDI	Built capital	Happiness index
SB	Access to Sanitation	Comprehensive wealth	Human capital
Sustainable HDI	Cardinal Green Index (CGI)	Consumption	Investment
Underweight Children	Consumption	EF	Life expectancy
WB	Enrolment Ratio	GS	Life satisfaction
WI	GDP	Happiness index	Produced capital
Work life balance	Life expectancy	Human capital	Social capital
GPI	Ordinal Green Index (OGI)	Investment	**LCA**
EF	Underweight Children	Life expectancy	CBA
French Dashboard on Sustainable Development	**Emergy**	Life satisfaction	DEA
Green national net product	EF	Produced capital	EF
GS	Environmental health	Social capital	EIOA
ISEW	GNRP	**ISEW**	MCDA
Pollution-sensitive HDI	Green net regional product	EF	MFA
Sustainable HDI	Information	French Dashboard on Sustainable Development	SFA
Well-being matrix		GPI	SLCA
Gini Index	**Ecosystem services**	Green national net product	**Age**
CO2 emission	Environmental health	GS	Employment

Crime rate	Index of dependence on ecosystem services (IDES)	Pollution-sensitive HDI	Income
Energy consumption	Landscape sustainability	Sustainable HDI	Population mobility
Expenditure on R&D	Poverty	**WI**	Education attainment
GDP	Sustainable Livelihoods	EF	Poverty
Life expectancy		ESI	Real estate values
Renewable energy	Biocapacity	GDP	**SB**
Unemployment	EF	HDI	EF
Water pollution		SB	ESI
Human capital	**Comprehensive wealth**	**Environmental efficiency of well-being (EWEB)**	GDP
Comprehensive wealth	GDP	EF	HDI
EF	HDI	Life satisfaction	WI
Life expectancy	Human capital		
Natural capital	Natural capital		

A wide range of SaW indicators have been presented in the discussion so far. One noticeable problem with selecting multiple SaW indicators is the unnecessary bunching of redundant indicators (Mitchell et al., 1995). For example, in Table 3, HDI is applied with GDP, life expectancy, education and income, which are themselves components of HDI. Therefore, studying them in conjunction with HDI will be unlikely to provide significantly new information, but will tend to replicate the results or characteristics of HDI (Grimes, Oxley, & Tarrant, 2014). Many studies have acknowledged this concern and have proposed several methods to avoid preventable redundancy in selecting multiple SaW indicators (Bossel, 2003, Mitchell et al., 1995, Rice & Rochet, 2005, Tanguay, Rajaonson, Lefebvre, & Lanoie, 2010).

Since our aim is to find high-quality SaW indicators with certain degree of comparability at a desired level (i.e. local, regional, international) and avoid redundancies, we propose to use the ranked matrix of SaW indicators by fuzzy determinants given in Table 4. In the matrix, composite indicators (such as EF, HDI, LCA etc.) are placed in the first row across columns and single indicators (such as Energy, Income, Disease) in the first column across rows ranked by the number of citations received by the publication they belong to. Indicators are sorted by the rank scores in ascending order from left to right and top to bottom. Each composite indicator is marked against its fuzzy components among single indicators to complete the matrix.

Ultimately, the matrix of ranked indicators becomes a tool to systematically study a growing number of SaW indicators. A set of indicators can be selected to comprehensively study SaW based on two key considerations: select indicators which are highly ranked by scholars in terms of citations; and indicators with minimum overlaps in terms of their components e.g. single indicator to avoid undesired redundancies. In other words, indicators from left to right and top to bottom of the matrix with a minimum number of similar determinants should be selected.

Table 4: Matrix of ranked indicators by fuzzy determinants

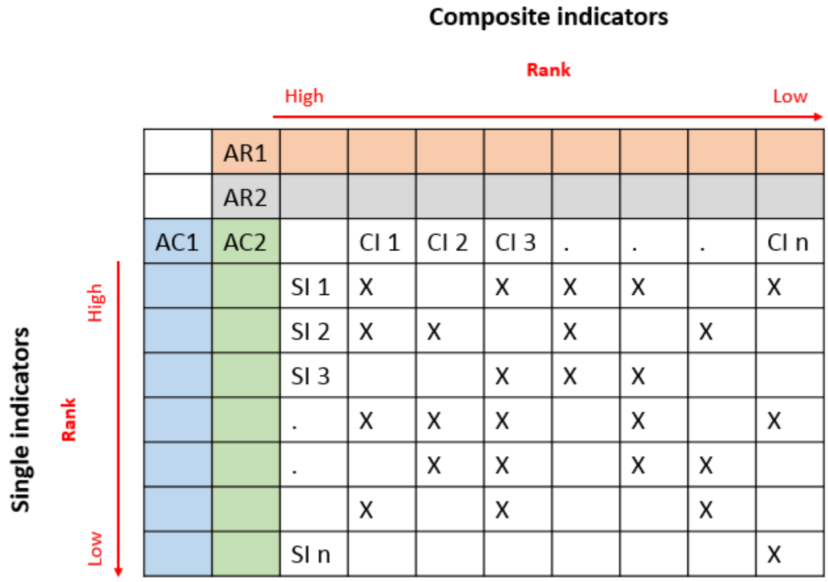
		EF	HDI	LCA	QOL	Comprehensive wealth	GS	GPI	Sustainable development assessment framework	ESI	WI	SB (surplus biocapacity)	ISEW	GNNP: Green national net product	BAHYs	QALY	Index of economic freedom	Environmental efficiency of well-being (EWEB)	Emergy	Sen's theory of well-being
	Times Cited	360	199	115	97	91	82	81	73	57	55	55	44	35	23	23	21	19	17	15
Ecosystem services/Ecosystem services accounting	1435	X				X	X					X	X					X		
Natural capital	441	X		X		X	X	X	X	X		X	X	X				X		
Environmental health	356	X		X		X	X	X	X	X		X	X	X				X		
Health	296		X		X			X	X		X									X
Aquaculture	157	X								X								X		
Energy	145	X		X			X											X	X	
Income	141		X	X	X	X	X	X	X		X		X	X						X
Disease	134				X											X				
Biodiversity	123	X		X	X										X			X		
River protection	122	X								X										
GDP	119		X	X		X	X				X		X	X				X		
Transport	116			X							X									
Water	113	X		X	X					X								X		
Human capital	98		X				X	X												
Forest	97	X		X	X					X		X						X		
GNP	93					X	X							X						
Food	89	X			X													X		
Renewable energy	84	X		X			X											X		
Participation	73				X						X									
Landscape sustainability	72	X		X														X		
Social capital	56				X	X		X	X											
Employee well-being	55				X															
Education	51		X		X		X		X		X									X
Industrial processes	47			X																
Natural resource management	46	X																X		
Sustainable fisheries	45	X																X		
Economic growth	43		X				X													
Life expectancy	43				X										X	X		X		X
Population	42		X		X						X		X							
Air quality	41	X		X	X					X		X						X		
Land use	40	X		X						X								X		
Age	39		X		X										X	X				X
Cultural heritage	37				X															X
Fair trade	36																			
Construction design	34			X																
Life satisfaction	34				X						X									
Consumption	34	X			X		X		X				X					X		
Self-management abilities	33																			X
Subjective well-being	33				X															
Industrial Sustainability	32			X																
Utility and Social Welfare	31				X															
Employment	30				X						X									X
Organizational well-being	29				X															
National wealth	29						X	X					X							
Sense of place	27										X									
Social well-being	27				X															X

Governance	26				X															
CO2 emission	26	X		X	X		X			X		X	X					X		X
Urbanization	25	X																X		
Fertilizer use	24	X																X		
Habitat conversion	24	X								X								X		
Produced capital	24	X				X	X											X		
Subsistence harvests	23			X																
Wages	23				X															
Work life balance	23				X															
FDI	21						X													
Exergy	20																		X	
Investment	20						X						X							
Intergenerational equity	16	X				X	X		X					X				X		
Justice	14										X									
Peace	14				X															

This matrix is helpful in determining which indicators should be preferred over others and what indicators become redundant after picking an indicator at the fuzzy determinant level. For advanced comparisons at the model level, researchers have often applied non-nested testing[11] or encompassing principles to determine the characteristics of rival models (Mizon & Richard, 1986). In addition, indicators in the matrix may also be assigned other attributes of interest such as scope, scale, and corresponding human need from Max-Neef's or Maslow's frameworks and the scope of assessment (i.e. local, national, regional etc.) in order to increase the relevance. Since a wide range of indicators has been discussed in this paper, it has not been possible to cover all these details.

A generic view of attributed ranked matrix of SaW indicators is shown in Figure 11 in which attribute rows (AR1, AR2, … ARn) and attribute columns (AC1, AC2, … ACn) are added on the top for composite indicators and at the left side of the matrix for single indicators respectively. For example, if we want to compare composite indicators of weak sustainability in Table 4, we may add a row of attributes for each indicator in the top of the first row to show the reader which composite indicators can address weak sustainability and the rest can be ignored.

Figure 11: Generic format of ranked matrix of SaW indicators



3.4 Conclusion

Indicators are increasingly recognised and widely applied as useful tools to monitor the progress towards SaW, for policy making, and public communication regarding social economic, environment and technological performance (Singh, Murty, Gupta, & Dikshit, 2009). However, the selection of SaW indicator from a huge collection of possible indicators used in the literature is a challenging task; and the choice of indicators is ordinarily influenced or biased by the researcher's particular view on SaW (Michalos, 1997). We have attempted to develop a hybrid method to broadly cover SaW indicators by combining the strengths of scientometrics and a traditional literature review. Benefits of this approach are twofold. Firstly, it helps in understanding major development in the area of SaW by identifying key trends and clusters among people, places, publications and collaboration from a huge collection of documents using modern computing power. In our scientometric analysis, we found that scholars from developed OECD countries, in particular the US and EU, play a vital role in the development and application of SaW indicators. Deeper analysis of core publications identified in the scientometric networks confirms that the SaW debate is grounded in the consumption and preservation of different types of resources. Heavily cited publications relate to natural resources compared to other forms of resources, for example, see (Carpenter et al., 2009, Costanza & Daly, 1992), underscoring the importance of natural resources in the SaW literature as well as highlighting the mechanics of natural resource management and natural resource accounting. Secondly, this method facilitates the comparison of the maximum number of indicators in a ranked matrix which serves as a powerful tool to compare, contrast, filter and select the ‘right’ set of high ranked indicators with minimum overlaps.

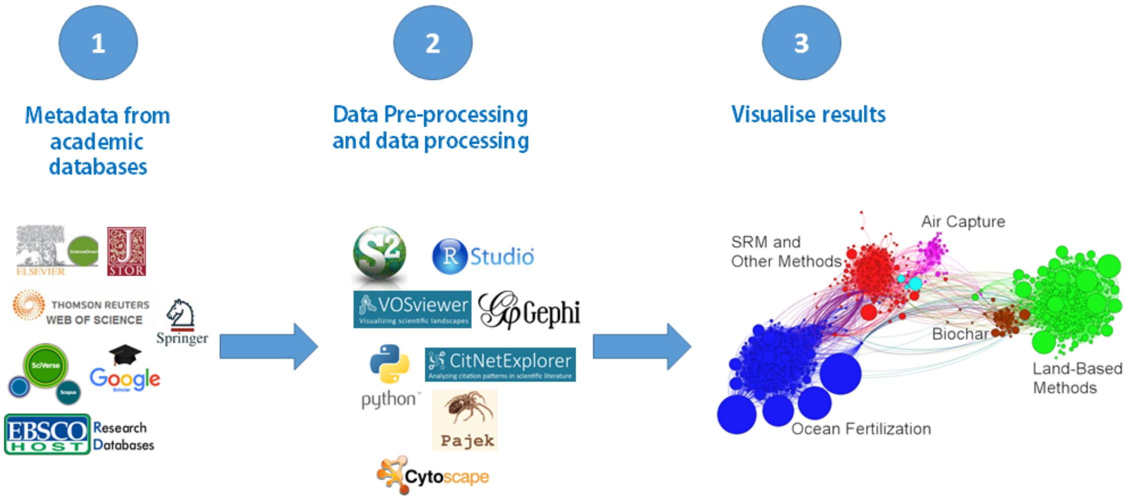
The methods applied in our study are flexible and can be extended in other studies, for example, we used the number of citations as the basis of indicator ranking which can be improved by adding more dimensions to estimate the ranking scores of indicators such as journal ranking, scope of application and the degree of comparability. In addition, a number of SaW attributes can be assigned to indicators to classify them further under social, economic and environmental categories or under several human needs determined in the frameworks of Max-Neef, Maslow or others.

3.5 Summary

Scientometrics deals with applying statistical methods to identify latent patterns for scientific research from enormous text corpus. We applied scientometric analysis to SaW literature available from ISI Web of Science to study it from several aspects. Our study has covered historical developments in the fields of SaW while identifying people, places, organisations and patterns of collaborations between them. In addition, we developed a systematic approach to identify and rank various indicators to quantify SaW. The novelty of this work lies in combining computing power to summarise large data with human analytical skills to extract useful information from it in order to maximise the scope of a study with better understanding of the focal subject, e.g. measuring SaW in our case.

In summary, some of the key strengths of scientometric analysis are: better understanding of broad literature which is not possible to develop from traditional methods, flexibility, reproducibility and wide applicability. Unlike traditional research, anybody can reproduce scientometric results and advance the research from there on normal computer systems. Figure 12 shows a generic methodological framework of scientometric analysis for other researchers to harness its explanatory power for any search query related to any discipline to conduct high-quality research in three simple steps: First of all, one downloads metadata against any search query from an academic search engine (e.g. ISI web of science, Scopus, Springer etc.). Second, this metadata file feeds into a scientometric package (e.g. CitNetExplorer, Sci2, VOSviewer, etc.) which applies several computer algorithms to build output. Finally, output files are ready to visualise and interpret. A quick guide to replicate the results of this paper or apply scientometric methods to conduct other studies is included in the appendix.

Figure 12: Generic flow chart of scientometric analysis



Logos in this picture are collected from google images.

3.6 Notes

1. Max-Neef's matrix of basic human needs categorises fundamental human needs as: subsistence, protection, affection, understanding, participation, recreation, creation, identity and freedom. Needs are also defined according to the experiential categories of being, having, doing and interacting, and from these dimensions, a 36 cell matrix is developed which can be filled with examples of satisfiers for those needs. For details please see Max-Neef, Elizalde, & Hopenhayn (1992) and Costanza et al. (2007).

2. Maslow's hierarchical needs framework is one of the best-known works on human needs whose early characterisation postulates a hierarchical pyramid of basic human needs stretching from fundamental physical needs at the bottom (e.g. air, food, water, etc.) to spiritual or moral needs on the top (love, justice, etc.). Maslow et al. (1970) and Jackson & Marks (1999).

3. Scientometrics is the study of measuring and analysing developments in science, technology and innovation. It emphasises the investigations in which the development and mechanism of science are studied by statistical and mathematical methods. For further details, please see: http://link.springer.com/journal/11192

4. Bibliometrics is the study of an interrelated set of documents, a prime example of which is the scientific literature. Some of its widely used applications are the comparative evaluation of countries, universities, research institutes, and individual researchers. It may also be used for other purposes such as developing a better understanding of the structure of a scientific field or determining developments in the research area (Hall, Jurafsky, & Manning, 2008, Juvan, Bartol, & Boh, 2005, Waaijer & Palmblad, 2015).

5. Topical maps have been developed in many widely used computer software environments in recent bibliometric studies called Sci2 developed by Cyberinfrastructure for Network Science Centre at the Indiana University.

6. Stop words are word which do not carry important information and therefore are excluded from the text before natural language processing. Most common example of stop words are "ïs", "the", "at", "on" etc. For details please see (Rajaraman & Ullman, 2011)

7. Stemming is the process of reducing inflected or derived words to their root stem. For example, words "argue", "argued", "argues", "arguing", and "argues" reduce to the stem "argue". For details please see (Rajaraman & Ullman, 2011)

8. Author and publisher map is a multi-layer map. Geo network is developed in computer program called Gephi which is overlaid on the open street base-map in another computer program called ArcMap.

9. Co-authorship map is developed in Sci2, arranged into geo-layout in Gephi and overlaid on the world base-map in ArcMap.

10. This community detection network is generated in Sci2. Community Detection algorithms look for subgraphs where nodes are highly interconnected among themselves and poorly connected with nodes outside the subgraph. Many community detection algorithms are based on the optimisation of the modularity - a scalar value between -1 and 1 that measures the density of links inside communities as compared to links between communities. The Blondel Community Detection finds high

modularity partitions of large networks in short time and that unfolds a complete hierarchical community structure for the network, thereby giving access to different resolutions of community detection (Blondel et al., 2008, Ding et al., 2014).

11. Two models are said to be non-nested when it is impossible to derive from the other either by limiting the process or imposing parametric restrictions (Vuong, 1989). The ability to encompass requires the model to explain the characteristics of the rival model (Mizon & Richard, 1986).

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Appendix

Table of acronyms

CBA	Cost benefit analysis
CGI	Cardinal green index
DEA	Data envelopment analysis
DMC	Direct material consumption
EF	Ecological footprint
EFCO2	Carbon adjusted ecological footprint
EIOA	Environmental input output analysis
EWB	Ecological well-being index
EWEB	Environmental efficiency of well-being
ESI	Environmental sustainability index
FDI	Foreign direct investment
GBL	Geo biosphere load
GDP	Gross domestic product
GPI	Genuine progress indicator
GS	Genuine savings
HDI	Human development index
HPI	Human poverty index
ISEW	The Index of Sustainable Economic Welfare
LCA	Life cycle assessment
LCC	Lice cycle costing
MCDA	Multi-criteria decision analysis
MFA	Material flow analysis
OECD	Organization for Economic Co-operation and Development
OGI	Ordinal green index
QALY	Quality adjusted life years
QOL	Quality of life
S	Sustainability
SaW	Sustainability and well-being
SFA	Stochastic frontier analysis
SB	Surplus biocapacity
UCSC	University of California, San Diego
W	Well-being
WI	Well-being index

Table 5: Glossary of terms, techniques and software packages applied to conduct scientometric analysis

Bibliometrics	The quantitative study of literatures as they are reflected in bibliographies
Citation network	Network of citation relations between items (e.g., publications, authors or journals)
CiteSpaceII	Software tool developed by Chen for "detecting and visualizing emerging trends and transient patterns in scientific literature"
CitNetExplorer	Software tool developed by Van Eck and Waltman "for visualizing and analysing citation networks of scientific publications"
- Mapping	Positioning of a subset of the publications in a citation network (usually selected based on their citation frequency) in a two-dimensional map in which the vertical dimension indicates time (i.e., the year of publication) and the horizontal dimension indicates the closeness of publications in the citation network.
- Clustering	Partitioning of the publications in a citation network into a number of groups (clusters). Publications assigned to the same group are closely connected to each other in the citation network.
Co-word map	Map of words (or terms), usually extracted from the titles and abstracts of scientific publications, showing the co-occurrence relations of the words (i.e., the number of publications in which two words occur together).
HistCite	Software tool developed by Eugene Garfield to "generate chronological maps" of scientific literature based on WoS input
Sci2	Software tool developed by a team led by Börner and Boyack that "is a modular tool set specifically designed for the study of science. It supports the temporal, geospatial, topical, and network analysis and visualization of scholarly datasets at the micro (individual), meso (local), and macro (global) levels."
VOSviewer	Software tool developed by Van Eck and Waltman "for analysing bibliometric networks", in particular networks based on citation and co- occurrence relations
- Mapping	Positioning of the items in a network in a two-dimensional map in such a way that strongly connected items tend to be located close to each other while weakly connected items tend to be located further away from each other. The horizontal and vertical axes have no special meaning. Only the relative distances between items carry meaning in a map.
- Clustering	Partitioning of the items in a network into a number of groups (clusters). Items assigned to the same group are closely connected to each other.
WebofScience (WoS)	Multidisciplinary bibliographic database produced by Thomson Reuters

Table 6: Top 25 SaW publications by number of citations

Title	Authors	GS Citations	WoS Citations	Year	WoS Citations (1995-2015)
Science for managing ecosystem services: Beyond the Millennium Ecosystem Assessment	Carpenter, Stephen R., et al.	792	382	2009	
Natural capital and sustainable development	Costanza, Robert, and Herman E. Daly	1229	299	1992	
The role of urban parks for the sustainable city	Chiesura, Anna	818	248	2004	
Interventions to promote walking: systematic review	Ogilvie, David, et al.	395	194	2007	
Healthy nature healthy people: 'contact with nature' as an upstream health promotion intervention for populations	Maller, Cecily, et al.	482	122	2006	
Effectiveness of alliances and partnerships for health promotion	Gillies, P	415	118	1998	
Preserving the biodiversity and ecological services of rivers: new challenges and research opportunities	Arthington, Ángela H., et al.	207	111	2010	
Main outcomes of the FRESH START trial: A sequentially tailored, diet and exercise mailed print intervention among breast and prostate cancer survivors	Demark-Wahnefried, Wendy, et al.	163	104	2007	
Current and future sustainability of island coral reef fisheries	Newton, Katie, et al.	190	101	2007	
Conceptualising successful partnerships	Dowling, Bernard, Martin Powell, and Caroline Glendinning	276	95	2004	
Sustainable development - is it a useful concept	Beckerman, Wilfred	435	91	1994	
Crisis or opportunity? Economic degrowth for social equity and ecological sustainability. Introduction to this special issue	Schneider, Francois, Giorgos Kallis, and Joan Martinez-Alier	250	73	2010	
Strategies and approaches in oral disease prevention and health promotion	Watt, Richard G.	235	73	2005	
Evaluating projects and assessing sustainable development in imperfect economies	Arrow, Kenneth J., Partha Dasgupta, and Karl-Göran Mäler	284	73	2003	
The poverty of cities in developing regions	Brockerhoff, Martin, and Ellen Brennan	198	72	1998	
Untangling the Environmentalist's Paradox: Why Is Human Well-being Increasing as Ecosystem Services Degrade?	Raudsepp-Hearne, Ciara, et al.	148	68	2010	
Frustrated achievers: Winners, losers and subjective well-being in new market economies	Graham, Carol, and Stefano Pettinato	229	68	2002	
Addressing Sustainability in Transportation Systems: Definitions, Indicators, and Metrics	Mihyeon Jeon, Christy, and Adjo Amekudzi	207	65	2005	
Motivations for Conserving Urban Biodiversity	Dearborn, Donald C., and Salit Kark	170	56	2010	
Contrasting and comparing sustainable development indicator metrics	Wilson, Jeffrey, Peter Tyedmers, and Ronald Pelot	161	55	2007	
The integration of economic and social aspects in life cycle impact assessment	Weidema, Bo P	151	55	2006	
Accounting for the value of ecosystem services	Howarth, RB; Farber, S	257	53	2002	
Measuring sustainable development - Nation by nation	Moran, Daniel D., et al.	200	52	2008	
Curiosity and pathways to well-being and meaning in life: Traits, states, and everyday behaviors	Kashdan, Todd B., and Michael F. Steger	143	52	2007	
Does Participating in Physical Activity in Outdoor Natural Environments Have a Greater Effect on Physical and Mental Wellbeing than Physical Activity Indoors?	Thompson Coon, J., et al.	184	51	2011	

NOTES:
GS: Google Scholar
WoS: Web of science

Table 7: List of indicators used in SaW papers by number of publications

Indicators	Count of Indicator(s)/Measure(s)	Sum of Citations
Ecosystem services	25	1032
Minimum level of natural capital	1	299
Health	24	295
Partnership	3	218
Walking	1	194
Ecosystem services accounting	3	152
Disease	18	134
River protection	2	122
Environment	24	115
Energy	10	104
Coral reef sustainability	2	102
Biodiversity	4	96
GNP	2	93
Social capital	5	88
Poverty	5	80

Transport systems sustainability	2	79
Sustainable development assessment	1	73
Forest	18	73
Participation	5	73
Bioenergy	2	72
Income distribution	1	68
Quality of life indicators	11	60
Food	11	59
Physical activity	2	58
Urban biodiversity	1	56
Employee well-being	4	55
Genuine progress indicator	6	53
Curiosity as a measure of well-being	1	52
Greenhouse gas accounting	1	49
Urban environmental performance	2	49
Mindfulness	3	48
Industrial processes	1	47
Air quality	2	41
ESS well-being module	1	38
Resilience in fisheries	1	38
Water availability	12	37
Cultural heritage	1	37
Fair trade	1	36
Landscape fragmentation analysis	1	36
Ecological footprint	1	35
Self-management abilities	1	33
EF	2	32
Industrial Sustainability	3	32
Utility and Social welfare	1	31
Sustainable fisheries	1	30
Comprehensive wealth	1	30
Organizational well-being	2	29
Construction design	7	29
Sustainability driven organizational design	1	28
Sense of place	1	27
Governance	1	26
Urbanization	4	25
Competitiveness	2	25
LCA	1	24
Sustainable diet	1	23
Work life balance	1	22
Earth stewardship	1	20
Economic growth	1	18
Behavioural medicine usage	1	18
The ecological sustainability trigon (EST)	1	18
Intergenerational equity	1	16
Corporate social responsibility	3	15
Peace	1	14
Urban greenspace	1	14
HDI	1	14
Drugs and alcohol use	1	13
Sustainable use of marine mammals	1	12
Water quality	3	12
Nutrition and feeding cost for pig farms	1	12
Rangeland ecosystems	2	12
Justice oriented framework	1	11
Responsible property investing (RPI)	1	11
Remediation	1	11
Total water demand	1	10
Human skills	1	10
Corn planting for biofuel	1	10
Emergy	2	10
Empowerment	1	9
Farmer's education	1	9
Product design	3	9
Yoga for disease management	1	9
Protected areas	1	9
Inclusive wealth	2	8
Coastal zone management	1	8
Aquaculture	2	8
Adaptive capacity	1	8
Adaptive governance	1	8
Geotraveler tendencies	1	7
Nutrition report	1	7

Growth metabolism in cultured juvenile fish	1	7
Biotechnology	1	7
Quality of schools	1	7
Transport systems for quality of life	3	7
Quality of universities	2	7
ICT	6	6
Retailing	1	6
Goal attainment	1	6
Sustainable behaviour	1	6
Pro-environment nature of a person	1	6
Regenerative work	1	6
Exposure to nanomaterial	1	5
Well-being from sustainable fisheries	1	5
Community prevention coalitions	1	5
Age	1	5
Rain-index insurance	1	5
Support groups	1	5
Skiing tourism	1	5
Religion and culture	2	5
Product generational dematerialization (PGD)	1	5
Micro finance	2	4
Subjective well-being	1	4
Home hygiene	1	4
Education of farmers	1	4
Agricultural Certifications	1	4
Restoration of ecosystem	1	4
Training of caregivers	1	4
Gain from green program	1	4
Dredging technology	1	4
Consumption patterns	3	4
Climate change	4	4
Yield	1	4
Research	2	4
Plant breeding processes	1	4
Sustainable fishing	1	3
Sewage Chemical Information Mining (SCIM)	1	3
Night time Satellite Imagery	1	3
Genetic gain in maize crop	1	3
Income inequality	1	3
Real estate prices	1	3
Justice	1	3
Role of genetics in aquaculture	1	3
Role of mining in community development	1	3
Sustainable levels of consumption	1	3
Exercise among older people	1	2
Urban diversity	1	2
Nature relatedness	1	2
Green Infrastructure	1	2
Land use	10	2
Free bus travel for older people	1	2
Wetlands spaces	4	2
Frustration	1	2
HWBI	1	2
Honey bee well-being	1	2
Land cover maps	1	2
Progress	1	2
Urban land use development	1	2
Purchasing power	1	2
Well-being of caregivers	2	2
Sustainable tourism and community well-being	1	2
Willingness to pay for the well-being of other species	1	2
Sustainable welfare	1	2
Recognition of unpaid work	1	2
Conservation	1	2
Karst landscapes	1	2
Clinical effectiveness	1	2
Sustainable real estate development	1	1
Income	1	1
Greenspace creation	1	1
Growth and equity	1	1
Well-being Composite Index (WCI)	1	1
Genuine saving	1	1
Farmers' education	1	1
Consumer's ethical believes	1	1

Gross national happiness	1	1
Social determinants of health (SDH)	1	1
Social Progress Indicators	1	1
Car sharing	1	1
Work disability	1	1
Sustainability of health care systems	1	1
Payment for ecosystem services	1	1
Feed	2	1
Green accounting	1	1
Sustainable consumption	3	1
Social and Environmental Inequalities Index (SEII)	1	1
Use of nano-biotechnology	1	1
Ecological inequality	1	1
Manual pit emptying	1	1
FDI	1	1
Alcohol consumption	1	1
Intellectual capital	5	1
Roads networks	1	1
Democracy and public policy	1	1
Capabilities and empowerment	1	0
Affordability	1	0
Urban microbiomes	1	0
Construction design	1	0
Mining and minerals for sustainable development	1	0
Economic growth and environmental health	1	0
Ecological systems	1	0
Sustainability education	1	0
Value of natural capital	1	0
Real estate development	1	0
Self-employment duration	1	0
Sustainable agriculture	1	0
Shadow prices	1	0
Sustainable and responsible investment (SRI)	1	0
Social expenditure	1	0
Sustainable Architecture	1	0
Resilience	1	0
Adjusted Net Saving (ANS)	1	0
Floods	1	0
Fund raising and collaborations	1	0
Waste water management	1	0
Reclamation	1	0
Demand for natural resources	1	0
Sustainable design	1	0
Human capital	1	0
Carrying capacity	1	0
Natural capitalism	1	0
Animal well-being and environmental health	1	0
Human shelter	1	0
Artificial neural network	1	0
Rainwater harvesting	1	0
GDP	1	0
Software quality	1	0
Sustainable food consumption	1	0
Sustainable society index	1	0
Sustainable housing	1	0
Human thermal sensation	1	0
Regulation for high seas	1	0
Agriculture and poverty reduction	1	0
Sustainable livelihoods and marine sustainability	1	0
Life-cycle nutrition	1	0
Sustainable manufacturing	1	0
Lifestyles of health and sustainability	1	0
Sustainable mine closures	1	0
Saving	1	0
Sustainable production	1	0
Water resources vulnerability	1	0
Rehabilitation and recovery from disaster	1	0
Scarcity of natural and human resources	1	0
Community supported agriculture (CSA)	1	0
Ecological engineering	1	0
Energy and environmental health	1	0
Farm resources	1	0
Parks	1	0
National accounts	1	0

Textile industry growth	1	0
Economic growth and entrepreneurship	1	0
Psychological well-being	1	0
No of pubs for rural well-being	1	0
Growth	1	0
Social behaviour	1	0
Tourism	3	0
Social carrying capacity	1	0
Job satisfaction	1	0
Social equity	1	0
Aborigines well-being	1	0
Societal well-being	1	0
Ethnicity	1	0
Solar energy	1	0
Birth giving	1	0
Human Well-Being Index (HWBI)	1	0
Education of sustainability	1	0
ISEW	2	0
Quality of education	1	0
Community sustainability	1	0
River run-offs	1	0
Quality of life	2	0
Income and leisure	1	0
Sustainable construction	1	0
Grand Total	**506**	**5548**

Table 8: List of multiple SaW indicators used together

Detail of measures	**Sum of Citations**
LCA, CBA	55
EF, ESI, GDP, HDI, SB, WI	55
EF, HDI	52
Natural resource accounting	49
Environmental health, Ecosystem services, Landscape sustainability	36
Ecosystem health assessment, EF, Natural resource availability, Quality of life	35
Natural capital, Life expectancy, Human capital, EF	34
Comprehensive wealth, Human capital, Natural capital	34
Age, employment, income, population mobility, education attainment, poverty, real estate values	30
Subjective well-being, National wealth, Environmental health	29
Green national net product, GS EF, ISEW, GPI, Pollution-sensitive HDI, Sustainable HDI, French Dashboard on Sustainable Development	28
GDP, HDI, Comprehensive wealth	27
Energy, GDP, Land use	25
Forest, Habitat conversion, Marine captures, Fertilizer use, Water pollution, Carbon emissions, Species threat	24
Ecosystem health of agro-ecosystems	24
LCA, SLCA, MCDA, SFA, DEA	23
BAHYs, QALY	23
Wages, Income, Subsistence harvests, Demographic change	23
Agricultural output, Labor productivity, Power investment, Fertilizer investment, Irrigation index, Rural electricity consumption, Income, Rural consumption level	23
FDI, Index of economic freedom, GS	21
Natural capital, Produced capital, Human capital, Consumption, Investment	20
Environmental efficiency of well-being (EWEB), EF, Life satisfaction	19
EF, Social welfare	18
GS, Natural resource accounting	17
EF, Population growth	17
ISEW	16
Economic growth, Income distribution	16
Natural capital, GS, Happiness index, Life satisfaction	15
Sen's theory of well-being	15
Ecosystem services	15
MFA, LCA, EIOA, EF	14
Exergy capture, Exergy dissipation, Storage capacity, Biotic water flow, Metabolic efficiency, Nutrient loss, Biotic diversity, Abiotic diversity	9
Week sustainability, Strong sustainability, Urban development	8
Environmental stewardship, Economic growth, Social well-being, Technological advancement, Performance management	8
EF, Emergy, Green net regional product	7
Forest management, Poverty, Land use	7
Green energy, Modular agriculture, Sustainable water using	7

Poverty, Ecosystem services	6
Index of dependence on ecosystem services (IDES)	6
Aquaculture, Coastal zone management, Fisheries, Marine conservation	6
Modified Socio-Environmental Vulnerability Index (M-SEVI)	6
Biocapacity, Ecosystem well-being index, EF	6
HDI, Ordinal Green Index (OGI), Cardinal Green Index (CGI), GDP, Human Poverty Index (HPI), Life expectancy, Underweight Children, Access to Sanitation, Enrolment Ratio, Consumption	6
Genetic diversity, Trees management	5
Energy, Food, Land, Water	5
Sustainable Livelihoods, Ecosystem Health	5
Ecological quality, Transitional waters	4
Weak sustainability, Strong sustainability	4
Marketing policies	4
Building design, Energy efficiency, Thermal Comfort	4
Built capital, Natural capital	4
Ecosystem services, Sustainable Livelihoods	3
Age, Labour participation, Illness duration	3
Water management	3
Climate change, energy	2
GDP, EF, Population	2
Energy, exergy, sustainability index	2
DMC, WB, EWB, ESI, EF, EFCO2, HDI, GBL, GDP, Happiness Index, QOL	2
Gini Index, Life expectancy, Crime rate, CO2 emission, Water pollution, Unemployment, GDP, Expenditure on R&D, Energy consumption, Renewable energy	2
Index of Regional Quality of Development	2
Food security, Livestock	2
EF, Life expectancy	1
Perception, Environment, Action, Relationship, Locality	1
Culture, Language, Sustainability of land	1
Economic growth, Social well-being, Energy Consumption	1
Biocapacity, EF	1
Age, Gender, Ethnicity, Location, Postcode. Country, Living with, Household size, Country of birth, Income, Health, Education, Relationship, Safety, Work life balance, Locality, HDI	1
Quality of Life Index, Sustainable Livelihoods Framework	0
Water and Sanitation, Energy, Health, Agriculture, Biodiversity	0
Sustainability assessment tools	0
GPI, Well-being matrix	0
Australian national Development Index	0
Positional Value, Willingness to pay, Life satisfaction	0
EF, Environmental health, GNRP, Emergy, Information	0
Review of sustainability indicators	0
Urban biodiversity	0
Multiple sustainability indicators to examine environmental health	0
Natural capital, Produced capital, Social capital	0
Human made capital, Natural capital	0

Table 9: Count of papers by journal name (for Figure 3)

Biology
3 ambio
1 arctic
1 arid land research and management
1 biological conservation
2 bioscience
1 cadernos de saude publica
1 canadian journal of forest research−revue canadienne de recherche foresti...
2 chemistry and ecology
1 ciencia e investigacion agraria
3 conservation biology
1 ecological applications
1 ecological complexity
1 ecological engineering
15 ecological indicators
3 ecological modelling
7 ecology and society
2 environmental conservation
4 environmental management
1 fisheries
1 fisheries research
1 forest ecology and management
1 forestry
4 forestry chronicle
1 freshwater biology
2 frontiers in ecology and the environment
1 global change biology
1 ices journal of marine science
1 integrated environmental assessment and management
1 international forestry review
2 international journal of environment and pollution
1 international journal of environmental research and public health
1 journal of apicultural research
1 journal of applied ecology
2 journal of food agriculture & environment
2 journal of forestry
1 journal of great lakes research
4 landscape and urban planning
2 landscape ecology
1 marine pollution bulletin
1 maydica
1 philosophical transactions of the royal society b−biological sciences
1 rangeland journal
1 regional environmental change
1 restoration ecology
1 south african journal of science

Biotechnology
1 current opinion in biotechnolo gy
1 food control
1 international biodeterioration & biodegradation

Brain Research
1 european archives of psychiatry and clinical neuroscience
1 journal of the american medical directors association
1 stroke

Chemical, Mechanical, & Civil Engineering
2 agriculture ecosystems & environment
1 applied energy
1 biofuels bioproducts & biorefining−biofpr
1 communications in soil science and plant analysis
1 computers & chemical engineering
1 desalination and water treatment
2 energy
3 energy and buildings
3 energy policy
1 energy sources part b−economics planning and policy
3 environmental engineering and management journal
1 experimental agriculture
1 hydrology and earth system sciences
2 journal of business economics and management
2 journal of sustainable agriculture
4 marine policy
1 ocean & coastal management
3 proceedings of the institution of civil engineers−engineering sustainability
1 proceedings of the institution of civil engineers−water management
1 renewable agriculture and food systems
1 resources conservation and recycling
2 resources policy
1 structure and infrastructure engineering
1 technological and economic development of economy
1 transport policy
2 transport reviews

1 transportation
1 waste management
1 water
1 water air and soil pollution
1 water sa

Chemistry
1 journal of nanoparticle research

Earth Sciences
6 applied geography
1 aquatic sciences
1 climatic change
1 computers environment and urban systems
2 current opinion in environmental sustainability
1 environment and planning b−planning & design
1 geologia croatica
1 global and planetary change
2 human ecology
1 hydrological sciences journal−journal des sciences hydrologiques
1 international journal of health geographics
1 natural hazards
1 physics and chemistry of the earth
1 polar record
1 polar research
4 sustainability science

Electrical Engineering & Computer Science
2 ethics and information technology
1 expert systems with applications

Health Professionals
1 academic medicine
1 american family physician
1 american journal of industrial medicine
1 annals of behavioral medicine
1 annals of biomedical engineering
3 applied research in quality of life
1 australian and new zealand journal of public health
2 bmc health services research
7 bmc public health
1 canadian journal of public health−revue canadienne de sante publique
1 canadian journal on aging−revue canadienne du vieillissement
1 cancer epidemiology biomarkers & prevention
1 disability and health journal
1 educational gerontology
3 evaluation and program planning
1 genes and nutrition
1 health affairs
1 health and quality of life outcomes
1 health education & behavior
1 health education journal
1 health education research
7 health promotion international
1 international journal of health services
1 journal of advanced nursing
1 journal of environmental health
1 journal of general internal medicine
1 journal of occupational rehabilitation
1 journal of public health
1 preventive medicine
1 proceedings of the nutrition society
1 psychology and aging
2 public health
1 quality of life research
1 rural and remote health
27 social indicators research
1 supportive care in cancer
1 trials

Humanities
1 aaa−arbeiten aus anglistik und amerikanistik
1 south asia−journal of south asian studies

Infectious Diseases
1 animal production science
1 annals of tropical medicine and parasitology
2 bulletin of the world health organization
1 journal of microbiology
6 plos one
1 revista brasileira de zootecnia−brazilian journal of animal science
1 revista panamericana de salud publica−pan american journal of public health
1 west indian medical journal

Medical Specialties
4 asia pacific journal of clinical nutrition
1 current biology
1 diabetes care
1 european journal of cardio−thoracic surgery

1 international journal of sexual health
1 journal of clinical oncology
1 journal of pediatrics
1 journal of rheumatology
1 public health nutrition

Social Sciences

1 administration in social work
1 african journal of business management
1 agriculture and human values
2 amfiteatru economic
1 annals of the american academy of political and social science
1 architectural science review
1 australasian journal of environmental management
1 australian economic review
1 australian geographer
3 australian journal of social issues
3 building research and information
2 clean technologies and environmental policy
1 contemporary clinical trials
1 cross cultural management−an international journal
1 current issues in tourism
1 drustvena istrazivanja
2 e & m ekonomie a management
1 ecohealth
34 ecological economics
1 economic and industrial democracy
1 economic theory
1 ekonomska istrazivanja−economic research
1 environment and development economics
1 environment and planning a
1 environment and planning c−government and policy
1 environment and urbanization
4 environmental & resource economics
2 environmental education research
2 environmental impact assessment review
1 environmental progress
1 environmental science & policy
2 environmental values
3 futures
1 gaia−ecological perspectives for science and society
8 global environmental change−human and policy dimensions
1 health & social care in the community
3 human ecology review
1 ids bulletin−institute of development studies
2 interdisciplinary science reviews
1 international journal of consumer studies
3 international journal of life cycle assessment
1 international journal of manpower
1 international journal of operations & production management
1 international journal of stress management
3 international journal of sustainable development and world ecology
1 international organization
1 journal of adolescent health
1 journal of african economies
1 journal of agricultural economics
2 journal of business ethics
1 journal of business venturing
7 journal of cleaner production
2 journal of development studies
1 journal of economic issues
1 journal of environmental economics and management
3 journal of environmental management
2 journal of environmental planning and management
1 journal of environmental psychology
2 journal of human development and capabilities
1 journal of infrastructure systems
1 journal of international development
2 journal of macromarketing
1 journal of organizational change management
1 journal of peace research
1 journal of planning education and research
1 journal of research in personality
1 journal of rural studies
1 journal of social issues
1 journal of social service research
3 journal of sustainable tourism
1 journal of the academy of marketing science
2 journal of travel research
1 journal of urban technology
1 journal of vocational behavior
1 kyklos
2 land use policy
1 man in india
1 management decision
1 motivation and emotion
3 oxford review of economic policy
1 personnel review
1 policy sciences
2 population and development review

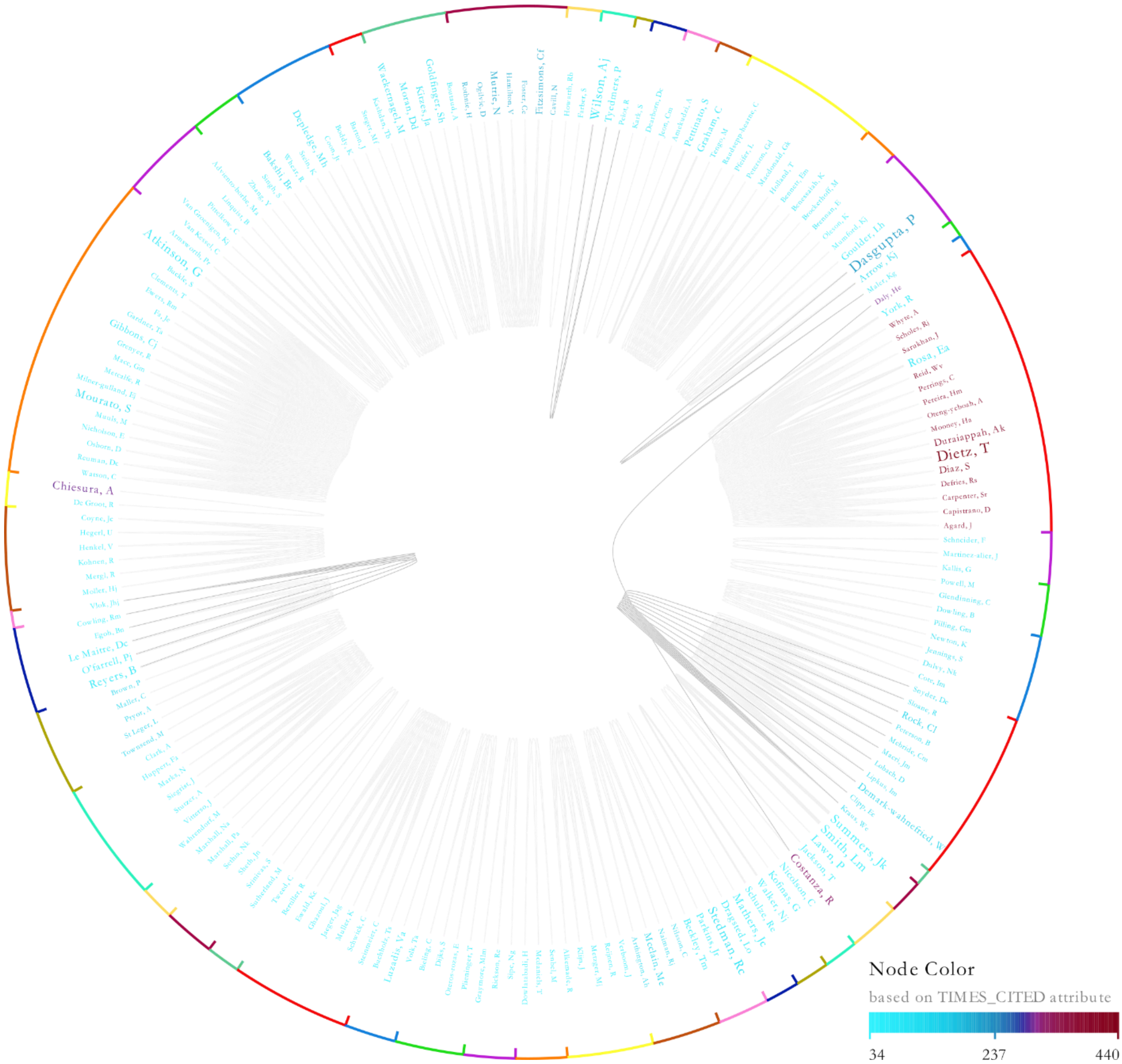
1 population and environment
1 production and operations management
1 quality & quantity
1 research in autism spectrum disorders
1 review of general psychology
1 revue d economie politique
1 romanian journal of economic forecasting
1 social & legal studies
1 social science research
3 society & natural resources
2 sociological forum
1 sustainable development
1 transformations in business & economics
1 urban policy and research
3 world development

Multiple Categories
1 british medical journal
5 environmental science & technology
5 proceedings of the national academy of sciences of the united states of am...
6 science of the total environment
1 social science & medicine
1 water science and technology

Unclassified
1 10th international multidisciplinary scientific geoconference: sgem 2010, vo...
1 16th international conference the knowledge−based organization: economi...
1 18th biennial isem conference on ecological modelling for global change a...
1 1st international conference ’economic scientific research − theoretical, em...
1 2008 portland international conference on management of engineering & t...
1 2011 ieee international professional communication conference (ipcc)
1 2012 ieee international symposium on sustainable systems and technolog...
1 2012 international conference in humanities, social sciences and global bu...
1 2013 conference on systems engineering research
1 2013 ieee business engineering and industrial applications colloquium (bei...
1 3rd international geography symposium, geomed2013
1 4th international conference citizens and governance for sustainable devel...
1 5th international conference of education, research and innovation (iceri 20...
1 8th international symposium of the digital earth (isde8)
1 advances in materials and systems technologies iii
1 advances in systems, computing sciences and software engineering
1 ageing & society
1 agile processes in software engineering and extreme programming, proce...
1 aice−bs 2012 cairo (asia pacific international conference on environment−b...
1 american forage and grassland council, vol 10, proceedings
1 annual review of animal biosciences, vol 2
1 annual review of economics, vol 2
1 bmj open
1 brownfield sites iii: prevention, assessment, rehabilitation and development...
1 building simulation
1 cambridge journal of regions economy and society
1 cers 2009 − 3rd central european conference in regional science, internatio...
2 cesb 10: central europe towards sustainable building − from theory to practi...
2 climate and land degradation
1 compare−a journal of comparative and international education
1 confronting contemporary business challenges through management innov...
1 conservation & society
1 creating global competitive economies: a 360−degree approach, vols 1−4
1 design and nature v: comparing design in nature with science and enginee...
1 early engagement and new technologies: opening up the laboratory
1 eco−architecture iii: harmonisation between architecture and nature
1 eco−architecture: harmonisation between architecture and nature
1 ecological economics reviews
1 ecological engineering: from concepts to applications, paris 2009
1 economic science for rural development: rural development and entrepren...
1 ecosphere
1 ecosystems and sustainable development iii
2 ecosystems and sustainable development iv, vols 1 and 2
1 ecosystems and sustainable development vi
1 energy & environment
1 energy, environment, ecosystems, development and landscape architecture
1 environmental economics and investment assessment ii
1 environmental engineering, vols 1−3
1 es2010: proceedings of asme 4th international conference on energy sust...
2 european framework for measuring progress (e−frame): proceedings of the...
1 first international conference on building energy and environment, proceedi...
1 food culture & society
1 from headwaters to the ocean: hydrological changes and watershed mana...
1 frontiers in psychology
1 frontiers of green building, materials and civil engineering, pts 1−8
1 geographic uncertainty in environmental security
1 german journal of agricultural economics
1 global health action
1 global policy
1 highway and urban environment
1 iceem 2012: 2012 2nd international conference on economic, education an...
1 icnc 2008: fourth international conference on natural computation, vol 7, pr...
1 idimt−2011: interdisciplinarity in complex systems
1 ifkad − kcws 2012: 7th international forum on knowledge asset dynamics, 5...
2 iforest−biogeosciences and forestry

1 ii european congress on chestnut
1 impacts of urban growth on surface water and groundwater quality
1 indoor air 2005: proceedings of the 10th international conference on indoor...
1 int conf on cybernetics and information technologies, systems and applicati...
1 international conference on environmental science and development (ices...
1 international journal of mining reclamation and environment
1 international symposium on underutilized plants for food security, nutrition, ...
1 journal of biomaterials and tissue engineering
1 journal of public health management and practice
1 landscape ecology and water management
1 linking ecology and ethics for a changing world: values, philosophy, and ac...
1 management of natural resources, sustainable development and ecologica...
1 medcoast 09: ninth international conference on the mediterranean coastal ...
1 medcoast 11, vols 1 and 2
1 mineral exploration and sustainable development, vols 1 and 2
2 modsim 2007: international congress on modelling and simulation: land, w...
1 monetary, banking and financial issues in central and eastern eu member ...
1 nature + culture
1 occupational safety and hygiene ii
1 overexploitation and contamination of shared groundwater resources: man...
1 oxford conference: a re−evaluation of education in architecture
1 proceedings for the 4th euro−asia conference on environment and corporat...
1 proceedings of 2009 international conference on public administration (5th)...
1 proceedings of 2012 international conference on complex systems (iccs12)
1 proceedings of 2012 international conference on public administration (8th)...
1 proceedings of the 10th european conference on research methodology fo...
2 proceedings of the 26th annual british columbia mine reclamation symposi...
1 proceedings of the 2nd european conference on intellectual capital
1 proceedings of the 5th european conference on management leadership a...
1 proceedings of the 6th international management conference: approaches ...
1 proceedings of the 6th knowledge cities world summit (kcws 2013)
1 proceedings of the 7th european conference on is management and evalu...
1 proceedings of the asme international design engineering technical confer...
1 proceedings of the asme international design engineering technical confer...
1 proceedings of the asme international mechanical engineering congress a...
1 proceedings of the first global forum of ecological economics in forestry
1 proceedings of the international workshop on tropical and subtropical fruits
1 proceedings of usm−aut international conference 2012 sustainable econom...
1 progress in environmental science and technology, vol ii, pts a and b
1 quantum sensing and nanophotonic devices
1 rational and sustainable development of water resources, vols i and ii
1 research for rural development 2012, vol 2
1 responding to environmental conflicts: implications for theory and practice
1 responsible marine aquaculture
1 rethinking global land use in an urban era
1 revue scientifique et technique−office international des epizooties
1 scientific world journal
1 social capital: a multifaceted perspective
1 social science and education
1 south african journal of animal science
1 strategies to enhance environmental security in transition countries
13 sustainability
1 sustainability in energy and buildings
1 sustainability of groundwater resources and its indicators
2 sustainable city iii: urban regeneration and sustainability
2 sustainable city iv : urban regeneration and sustainability
1 sustainable city vi: urban regeneration and sustainability
1 sustainable development and planning ii, vols 1 and 2
1 sustainable development and planning iv, vols 1 and 2
1 sustainable energy production and consumption: benefits, strategies and e...
1 transactions on emerging telecommunications technologies
1 transport research arena 2012
1 vision 2020: sustainable growth, economic development, and global comp...
1 waste and biomass valorization
1 water science and technology−water supply
1 wealth creation in the minerals industry: integrating science, business, and...
1 world congress on administrative and political sciences

Figure 8 full: Community detection within co-authorship networks of SaW



A quick guide

The followings steps illustrate a quick but powerful guide to run scientometric analysis without any computer programming skills:

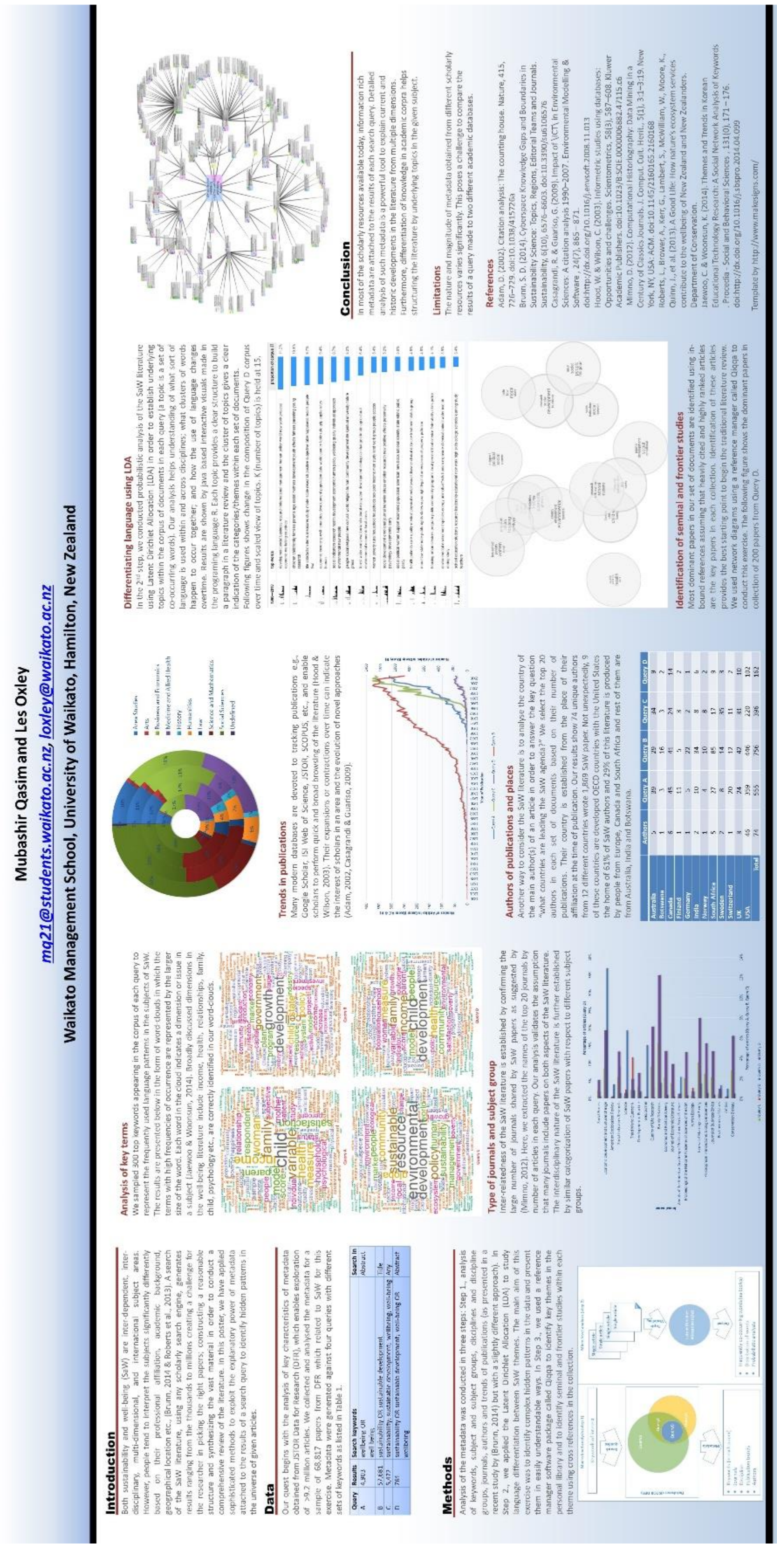
1. Make a search query in ISI Web of Science; this may find results ranging from hundreds to hundreds of thousands of publications. These results can be filtered and/or sorted on certain criteria such as publication date, citation scores etc.

2. Export results as "Save to Other File Formate" with Record Content "Author, Title, Source, Abstract" and File Format as "Plain Text". (Please note ISI Web of Science allows only 500 results per download. If you have results more than that, you can download in sets of 500 results in multiple files.)

3. This metadata in text files can be directly imported to scientometric softwares CitNetExplorer, VOSViewer, Sci2 without any treatment. VOSViewer, CitNetExplorer are easy to use self-explanatory packages to run several scientometric analysis. For example, In VOSViewer, co-citation map (figure 4), topic modelling, key-term map (figure 10) , co-authorship analysis etc. can be executed with the above dataset. The network between citations to explain evolution of knowledge (figure 9) can be made in CitNetExplorer. Sci2 is advanced software with several sophisticated scientometric features. A large number of scientometric algorithms are listed in Sci2 menus. Results can be visualised within the same software from visualisation options. Sci2 website https://sci2.cns.iu.edu/ has comprehensive step-by-step guide for different types of analysis.

Chapter 4: Topic modelling

This chapter is comprised of three components: i) conference poster ii) a poster paper[22] and a detailed working paper.



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[22] Qasim, M., & Oxley, L. (2015). "What Came First – Wellbeing or Sustainability?" A Systematic Analysis of The Multi-Dimensional Literature Using Advanced Topic Modelling Methods. 15th International Conference of the International Society for Scientometrics and Informetrics.

4.1 "What Came First – Wellbeing or Sustainability?" A Systematic Analysis of The Multi-Dimensional Literature Using Advanced Topic Modelling Methods

4.1.1 Introduction

Both sustainability and well-being (SaW) are inter-dependent, inter-disciplinary, multi-dimensional, and international subject areas. However, people tend to interpret the subjects significantly differently based on their professional affiliation, academic background, geographical location etc., (Brunn, 2014 & Roberts et al., 2013). A search of the SaW literature, using any scholarly search engine, generates results ranging from the thousands to millions creating a challenge for the researcher in picking the right papers; constructing a reasonable structure and synthesizing the vast material in order to conduct a comprehensive review of the literature.

The work presented here relates to the use of a sophisticated method to exploit the explanatory power of metadata, attached to the results of a search query, to identify hidden patterns in the universe of given articles. The methods and metadata used to conduct the systematic analysis are briefly discussed under following headings.

4.1.2 Components of systematic literature analysis

4.1.2.1 Acquisition of data

Our quest begins with the analysis of key characteristics of metadata obtained from JSTOR *Data for Research* (DFR), which enables exploration of > 9.2 million articles. We collected and analysed the metadata for a sample of 68,817 papers from DFR which related to SaW for this exercise. Metadata were generated against four queries with different sets of keywords as listed in Table 1. Analysis of the metadata was conducted in three steps: Step 1., analysis of keywords, subject and subject groups, disciplines and discipline groups, journals, authors and trends of publications (as presented in a recent study by (Brunn, 2014) but with slightly different approach). In Step 2., we applied the Latent Dirichlet Allocation (LDA) to study language differentiation between SaW themes. The main aim of this exercise was to identify complex hidden patterns in the data and present them in easily understandable ways. In Step 3., we used a reference manager software package called *Qiqqa* to identify key themes in the personal library and to identify seminal and frontier studies within each theme using cross references in the collection.

Table 1: Detail of search queries.

Query	Results	Search keywords	Search in
A	4,903	wellbeing OR well-being	Abstract
B	57,681	sustainability OR sustainable development	Title
C	5,472	Sustainability OR sustainable development AND wellbeing AND well-being	Any
D	761	sustainability OR sustainable development AND well-being OR wellbeing	Abstract

4.1.3 Analysis of keyterms

We sampled 300 top keywords appearing in the corpus of each query to represent the frequently used language patterns in the subjects of SaW. The results are presented in the form of word-clouds in which the terms with high frequencies of occurrence are represented by the larger size of the word. Each word in the cloud indicates a dimension or issue in a subject (Jaewoo & Woonsun, 2014). Broadly discussed dimensions in the well-being literature include income, health, relationships, family, child, psychology etc., are correctly identified in our word-clouds.

4.1.4 Type of journals and subject group

Inter-relatedness of the SaW literature is established by confirming the large number of journals shared by SaW papers as suggested by (Mimno, 2012). Here, we extracted the names of the top 20 journals by number of articles in each query. Our analysis validates the assumption that many journals include papers on both aspects of the SaW literature. The interdisciplinary nature of the SaW literature is further established by similar categorization of SaW papers with respect to different subject groups.

Trends in publications

Many modern databases are devoted to tracking publications e.g., as Google Scholar, ISI Web of Science, JSTOR, SCOPUS, etc., and enable scholars to perform quick and broad browsing of the literature (Hood & Wilson, 2003). Their expansions or contractions over time can indicate the interest of scholars in an area and the evolution of novel approaches (Adam, 2002, Casagrandi & Guariso, 2009).

In our analysis, we find the first article related to Query A, appears in 1919 and the number of publications remains trivial until the 1970's. Thereafter, a huge influx of papers begins in the late 1970's with 30 papers per year, peaking at 311 papers in 2012. In contrast, papers related to sustainability in Query B started much earlier with the first paper published in 1800. This number reaches to 50 papers per year in the next 100 years and steadily increase thereafter for another 50 years to around 250 papers per year in 1950. Post-1950, the number of scholarly articles grow five fold over next 5 decades and peaked in 2005 at 1304 papers per year. Articles related to both SaW in Query C emerge in the late 1970's and grow exponentially over the next 40 years. As Query D is a subset of Query C they exhibit similar trends. A comparison of these trends with the papers in the entire DRF corpus of 9.3 million articles indicates the level of interest of the scholars over different years.

4.1.5 Authors of publications and places

Another way to consider the SaW literature is to analyse the country of the main author(s) of an article in order to answer the key question "what countries are leading the SaW agenda?" We select the top 20 authors in each set of documents based on their number of publications. Their country is established from the place of their affiliation at the time of publication. Our results show 74 unique authors from 12 different countries wrote 1,869 SaW paper. Not unexpectedly, 9 of these countries are developed OECD countries with the United States the home of 61% of SaW authors and 29% of this literature is produced by people from Europe, Canada and South Africa and rest of them are from Australia, India and Botswana.

4.1.6 Differentiating language using LDA

Finally, we conducted probabilistic analysis of the SaW literature using Latent Dirichlet Allocation (LDA) in order to establish underlying topics within the corpus of documents in each query (a topic is a set of co-occurring words). Our analysis helps understanding what sort of language is used within and across disciplines; what clusters of words happen to occur together; and how the use of language changes overtime. Results are shown by java based interactive visuals made in the programing language R. Each topic provides a clear structure to build a paragraph in a literature review and the cluster of topics gives a clear indication of the categories/themes within each set of documents.

4.1.7 Identification of seminal and frontier studies

Most dominant papers in our set of documents are identified using in-bound references assuming that heavily cited and highly ranked articles are the key papers in each collection. Identification of these articles provides the best starting point to begin the traditional literature review with. We used network diagrams using a reference manager called Qiqqa to conduct this exercise.

4.1.8 Validation of results

The results are validated using the metadata from another widely used scholarly source called Web of Science. Most of our results exhibits the same characteristics as the results of DFR data.

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Adam, D. (2002). Citation analysis: The counting house. *Nature*, *415*, 726–729. doi:10.1038/415726a

Brunn, S. D. (2014). Cyberspace knowledge gaps and boundaries in sustainability science: Topics, regions, editorial teams and journals. *Sustainability*, *6*(10), 6576–6603. doi:10.3390/su6106576

Casagrandi, R. & Guariso, G. (2009). Impact of ICT in environmental sciences: A citation analysis 1990–2007. *Environmental Modelling & Software*, *24*(7), 865 – 871. doi:10.1016/j.envsoft.2008.11.013

Hood, W. & Wilson, C. (2003). Informetric studies using databases: Opportunities and challenges. *Scientometrics*, *58*(3), 587–608.

Mimno, D. (2012). Computational historiography: Data mining in a century of classics journals. *Journal on Computing and Cultural Heritage*, *5*(1), 3:1–3:19. doi:10.1145/2160165.2160168

Roberts, L., Brower, A., Kerr, G., Lambert, S., McWilliam, W., Moore, K., ...Blaschke, P. (2013). *A good life: How nature's ecosystem services contribute to the wellbeing of New Zealand and New Zealanders.* Retrieved from https://www.doc.govt.nz/Documents/science-and-technical/sap258entire.pdf

Jaewoo, C. & Woonsun, K. (2014). Themes and trends in Korean educational technology research: A social network analysis of keywords. *Procedia - Social and Behavioral Sciences*, *131*(0), 171 – 176. doi:10.1016/j.sbspro.2014.04.099

4.2 Analysis of SaW literature using LDA

4.2.1 Preamble

Although the direct connection between multi-dimensional sustainability and well-being (SaW) has not been well explored in the literature. Nevertheless, there exists a consensus among researchers from various backgrounds that the main aim of all development endeavours should be the improvement of human well-being (Akenji & Bengtsson, 2014, Kaivo-oja, Panula-Ontto, Vehmas, & Luukkanen, 2014, Kjell, 2011, Sengupta, 2002).

Both SaW are multi-dimensional, inter-disciplinary and international in their nature. People tend to interpret these subject matters significantly differently based on their personal world-view and professional or academic backgrounds. This eventually leads to a variety of policy solutions which may not be comprehensible and mutually harmonious.

Definition of sustainable development by the World Commission on Environment and Development as an idea of the equitable use of inter-temporal resources for inter-generational equity is commonly accepted in a broader sense. Which is, the present generation should use natural capital, produced capital and human capital in a way that future generations are able to maintain the at least the same level of well-being. Even if this definition is widely accepted, it remains important to rigorously define sustainability by mainly taking natural capital with other forms of capital into the account and develop precise measures around it in order to plan and track the progress (Agarwala, 2012, Anielski, 2001, Kulig, Kolfoort, & Hoekstra, 2010, Sengupta, 2002).

Similarly, well-being, in a broader sense, is understood as a set of objective and subjective components and in-built factors required for flourishing life positively. It is estimated subjectively in psychology, however, in other disciplines, it is comprised of a range of social indicators to observe objective well-being at a broader level (Defra, 2009, Galloway, Bell, Hamilton, & Scullion, 2006, Roberts et al., 2013, Sengupta, 2002). In general, higher levels of production and consumption[23] of goods and services are associated with higher economic growth and thus result in higher human well-being (in form of utility derived from consumption) in the literature of economics (Frey & Stutzer, 2002). However, in the field of psychology, sociology, medicine, gender, religion, demography and within their sub-disciplines well-being differs significantly in terms of scope, definition, and measures (Galloway et al., 2006).

Therefore, before going into empirical analysis of SaW, it is imperative to develop a clear understanding of the complexities of these two inter-disciplinary and presumably overlapping fields to better understand the links between them; and to identify/develop suitable measures to quantify them. To deal with these complexities, this paper first presents a macro-level analysis of SaW literature through key bibliometric visuals (i.e. an overview of key terms, journals, subject groups, trends of publications, people, places etc.) to show its emergence and evolution over time.

After that, we attempt to establish SaW as a unified subject matter by exploring the semantic links between SaW literature. The suitable method to study semantic relationships in the collection of documents is the class of probabilistic methods called "topic models" (McFarland et al., 2013) (i.e. Latent Dirichlet Allocation (LDA), (Blei, Ng, & Jordan, 2003)). We used Mallet implementation (McCallum, 2002) of LDA to identify topics in SaW literature. Finally, these topics are then consolidated into a theoretical framework which links dimensions of sustainability with dimensions of well-being in the light of traditional literature review. Eventually, this novel approach systematically joins the two fields and build a solids foundation to conduct further research on SaW as one subject.

Paper structure

This paper is presented in three parts: part one deals with the macro level analysis of SaW literature using bibliometric data from the search results of JSTOR database; part two is about micro-level analysis of SaW literature i.e. topic modelling (LDA) of the collection of documents from JSTOR using word count data for each article in the collection and finally in part three we organized topics

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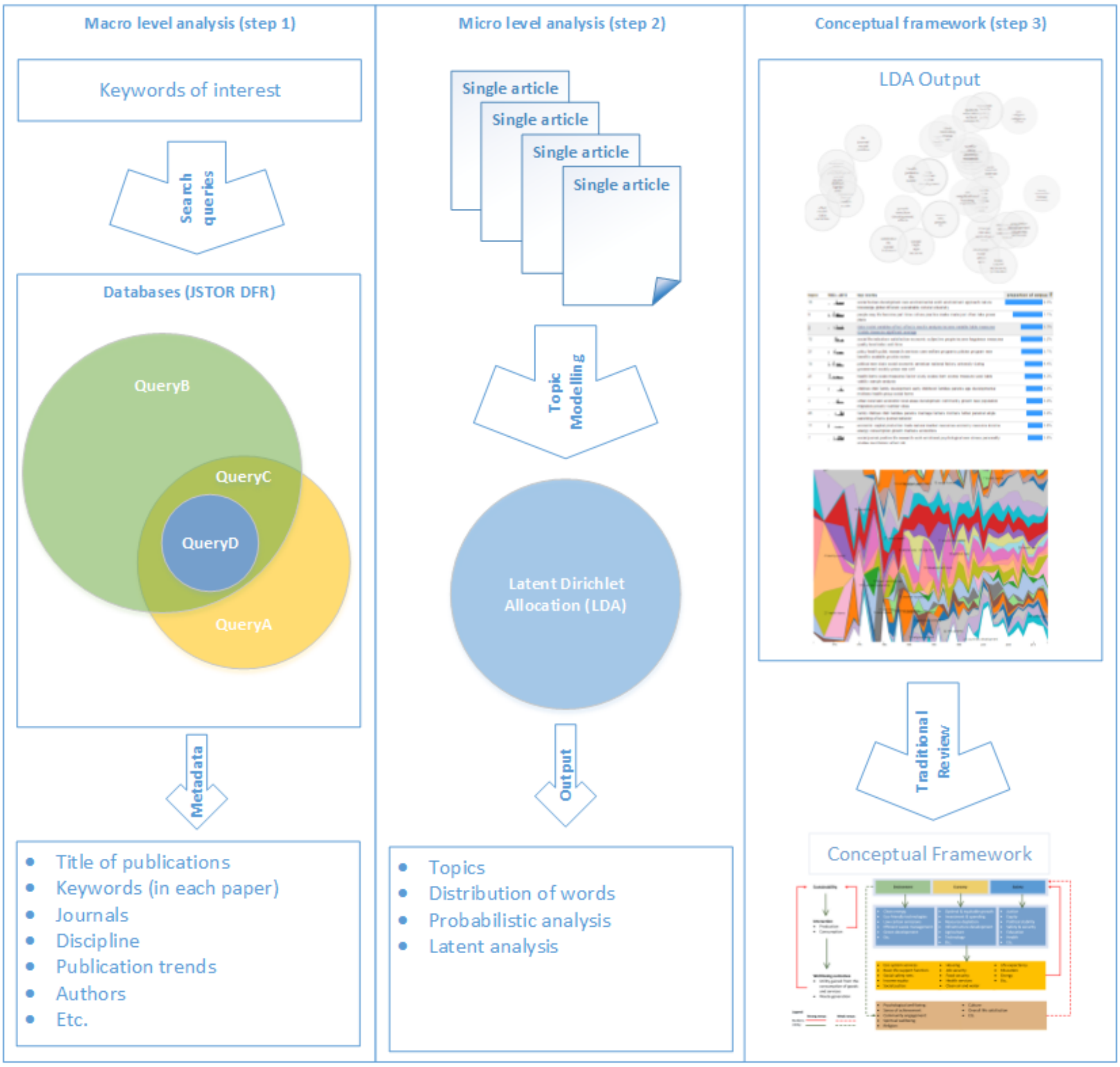
[23] In this paper term consumption refer to both consumption of input matrials for production of goods and services and final consumption by the end consumers.

identified in LDA analysis into a conceptual framework which links sustainability and well-being in the light of traditional literature review. Figure 1 illustrates the visual structure of the paper.

Figure 1: Paper plan



4.2.2 *Analysis of literature at a macro level*

Our quest for knowledge begins with the analysis of the key characteristics of metadata obtained from JSTOR Data for Research (DFR[24]) attached to the search results of SaW against four search queries using a different set of keywords. In this part, we analysed keywords, subject and subject groups, disciplines and discipline

[24] JSTOR DFR is a self-service tool that allows computer scientists, digital humanists, and other researchers to select and interact with content on JSTOR. Created in 2008, DFR enables exploration of both scholarly journal literature (over 9.29 million journal articles) and a set of primary resources. Source: dfr.jstor.org

groups, journals, people and trends of publications (as presented in a recent study by (Brunn, 2014) with slightly different approach) to capture high-level characteristics of SaW literature.

Table 1: Detail of search queries

Query	No. of results	Search Criteria		
		Search keywords	**Search in**	**Language**
A	4,903	wellbeing OR well-being	Abstract	English
B	57,681	sustainability OR sustainable development	Title	English
C	5,472	Sustainability OR sustainable development OR wellbeing AND well-being	Any	English
D	761	sustainability OR sustainable development AND wellbeing OR well-being	Abstract	English

Source: Numbers of results against each query from dfr.jstor.org

The metadata for a sample of 68,817 papers related to SaW were collected against four search queries from the universe of 9.29 million articles, book reviews, editorials etc. using different sets of keywords given in Table 1. Search criteria, from fuzzy to fine keyword search, was established based on the number of results generated against each query in order to keep the sample size reasonable. For example, if a search query returned over 100,000 articles without applying any filter (i.e. looking for keywords in the whole document), we narrowed down the results by looking for keywords "in abstract" field only which returned a lesser number of papers with a higher degree of relevance. For example, Query A returned 193,385 results when keywords were searched in the whole document. Therefore, to exclude weakly relevant results and make the sample size reasonable, keywords were searched in the abstract field only. With this criteria, 4,903 papers were retrieved.

When the number of search results from the abstract field was still higher than 100,000, keywords were searched in the title field only. For example, Query B generated over 2.6 million results without any filters in place, and this number was decreased to 121,746 results with "in abstract" filter on. To narrow down these results further, keywords were searched in the title field only which generated the final 57,681 results. Query C returned only 5,472 papers related to both SaW without any filter by looking for keywords in the whole body of documents, therefore, no additional filters were applied in this case. Since the articles which are highly relevant to both SaW are the focus of the study, results of Query D gives the finest subset of the documents retrieved from Query C by searching for the keywords in the abstract field. Final search results for all four queries are summarized in Table 2.

Table 2: Detail of search results against each query

Article type	Query A	Query B	Query C	Query D
Book review	11	1,831	311	4
Editorials	1	88	4	-
Journal	4,880	53,843	4,613	755
Miscellaneous	11	1,774	544	2
News	-	145	-	-
Total	4,903	57,681	5,472	761

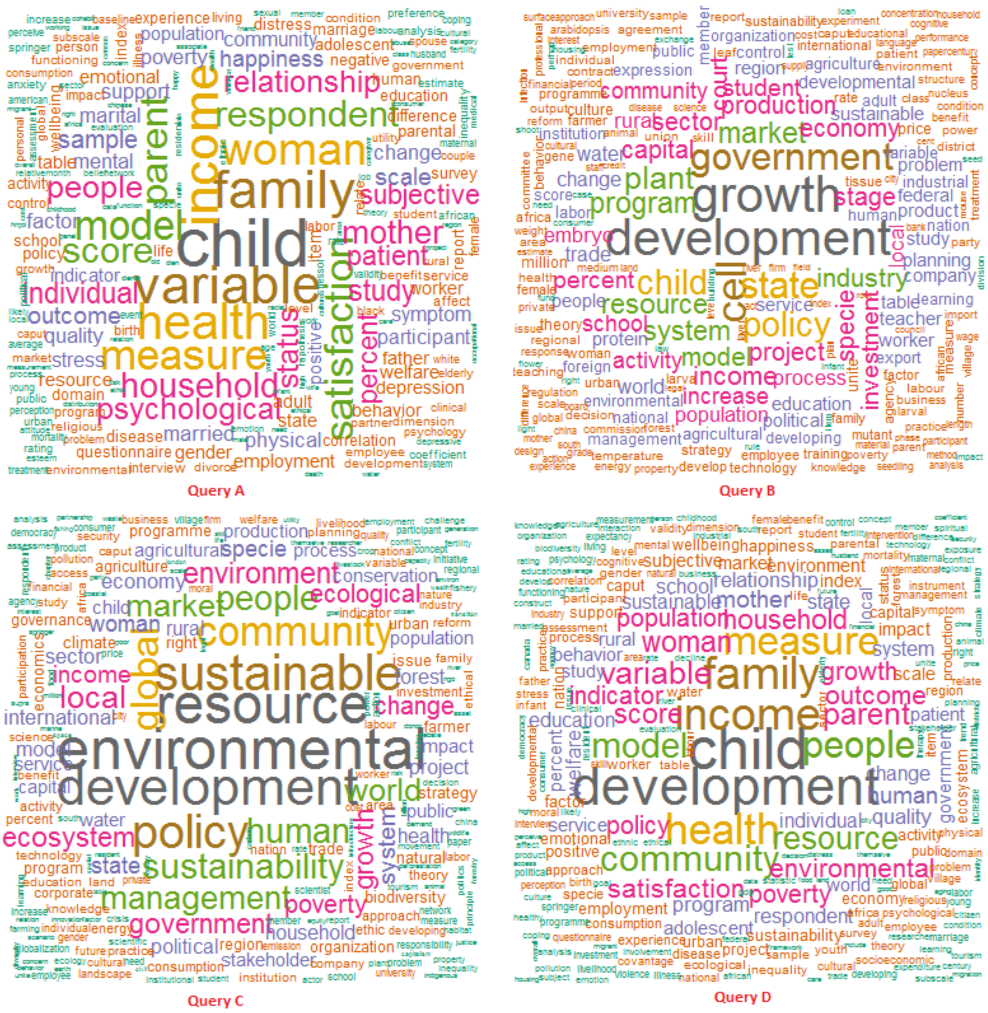
Source: Numbers of results against each query from dfr.jstor.org

4.2.2.1 Overview of top key terms

Analysis of keyword and meta-data has been increasingly adopted by the researchers of experimental studies and social sciences. A number of studies have applied keyword analysis to identify key themes, trends patterns in various contexts (Agarwala, 2012, J. B. Jackson, Miller, Oka, & Henry, 2014, Matysiak & Vignoli, 2008, Paré, Trudel, Jaana, & Kitsiou, 2015, Waldorf & Byun, 2005). For instance, (Jaewoo & Woonsun, 2014) analysed 645 papers written by Korean researchers with an objective to find themes and trends in Korean educational technology; (Casagrandi & Guariso, 2009) analysed metadata of publication during the period of 1990 – 2007 to analyse the impact of ICT in environmental sciences; (Matysiak & Vignoli, 2008) conducted meta-analysis to model the relationship between fertility and women's employment; (van Meter, 2005) applied meta-analysis to classify literature review and so on.

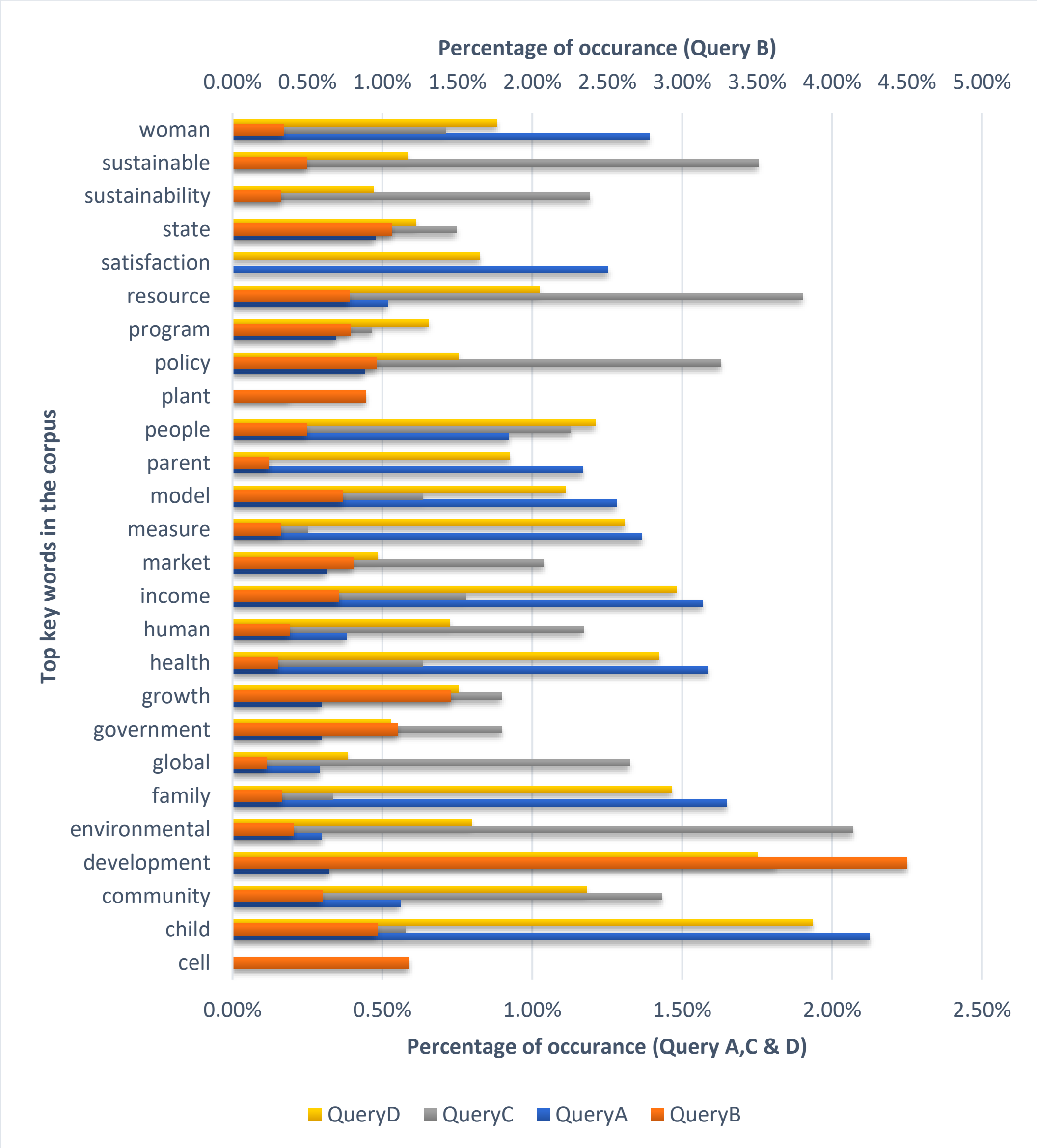
We sampled top 300 frequently occurring keywords in the whole corpus of each query results to capture frequently used set of words. The results are summarised in the form of word-clouds given in Figure 2. Terms with relatively large text size in a word-cloud indicate prevailing terms with high frequencies of occurrence. According to Jaewoo & Woonsun (2014) keywords with high frequencies indicates their importance in a subject. For example broadly discussed dimensions of well-being in the existing literate including income, health, relationships, family, child, psychology etc. are correctly identified in the word-cloud for Query A. Terms related to sustainability from economic, environmental and social perspectives such as: government, growth, development, investment, industry, production, etc. are dominant in the word-cloud of Query B. As expected, dominant terms in the literature of sustainability and well-being independently are seen together in the word-clouds for Query C and Query D which combine SaW literature.

Figure 2: Word clouds top 300 keywords in 4 queries



To make it more specific, top 10 frequently occurring words with their respective percentage of occurrence in the corpus of each query are summarised in Figure 3. The overall pattern in the chart validates our argument that vital issues, concerns or dimensions of well-being represented (represented by frequently used words) are equally important in the world of sustainability. There is an exception of word "cell" which belongs to well-being corpus only. This might be due to the fact that the literature related to human, animal and plant well-being (from a health perspective) represents a major proportion of well-being corpus in which term "cell" is exclusively and frequently used.

Figure 3: Top ten frequently occurring words by query

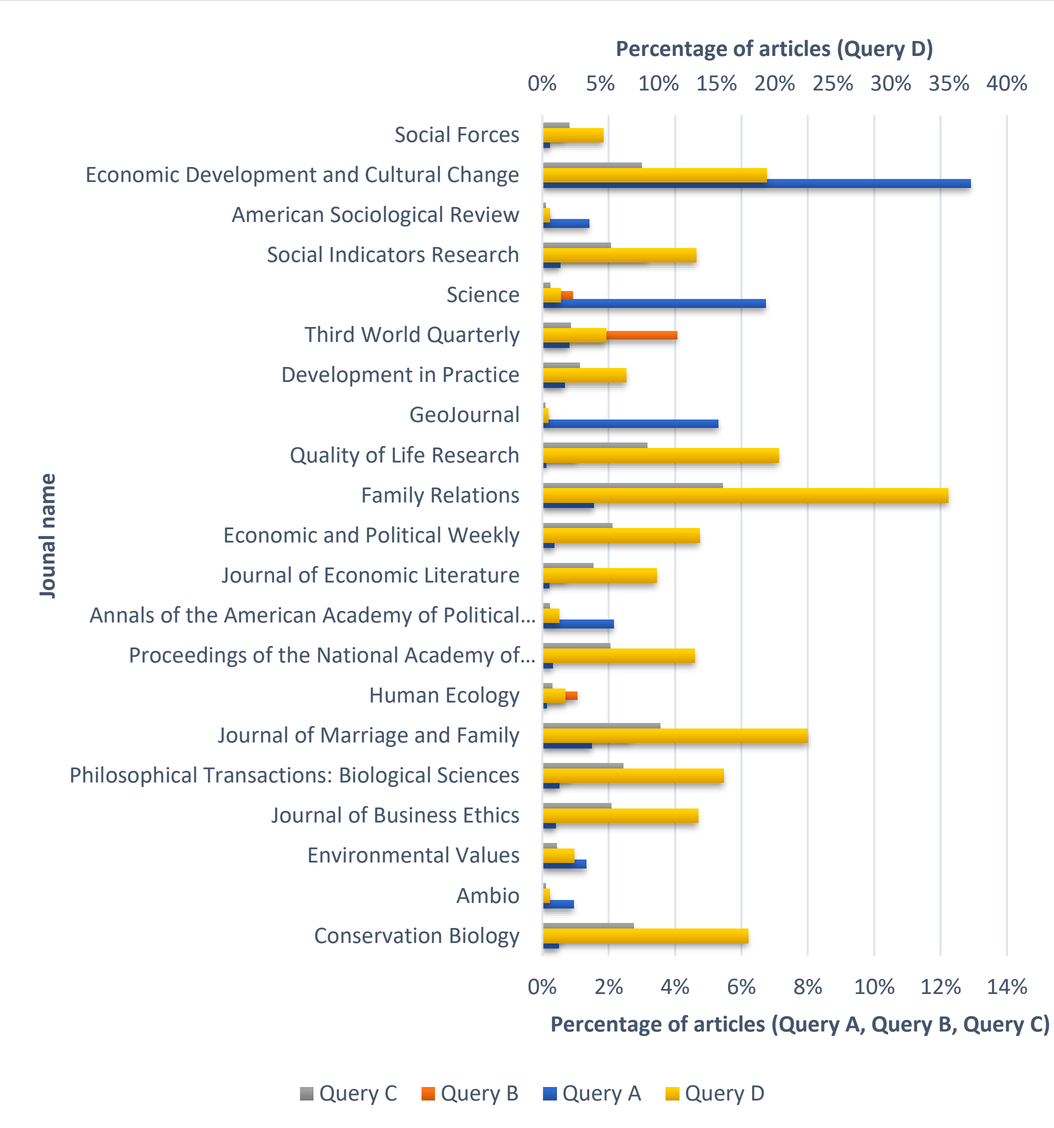


Note: Query B represents the largest number of documents reflected by higher frequencies of each word, therefore it is scaled on the secondary axis of the graph.

4.2.2.2 Type of journals

Type of journals shared by inter-disciplinary studies is another important indicator to establish the relationship between over lapping themes (Brunn, 2014, Juvan, Bartol, & Boh, 2005, Paré et al., 2015). In this part, we extracted the names of top 20 journals by their number of articles found in each query. Figure 4 validates the assumption of most of the journals listed below contains articles from both SaW queries.

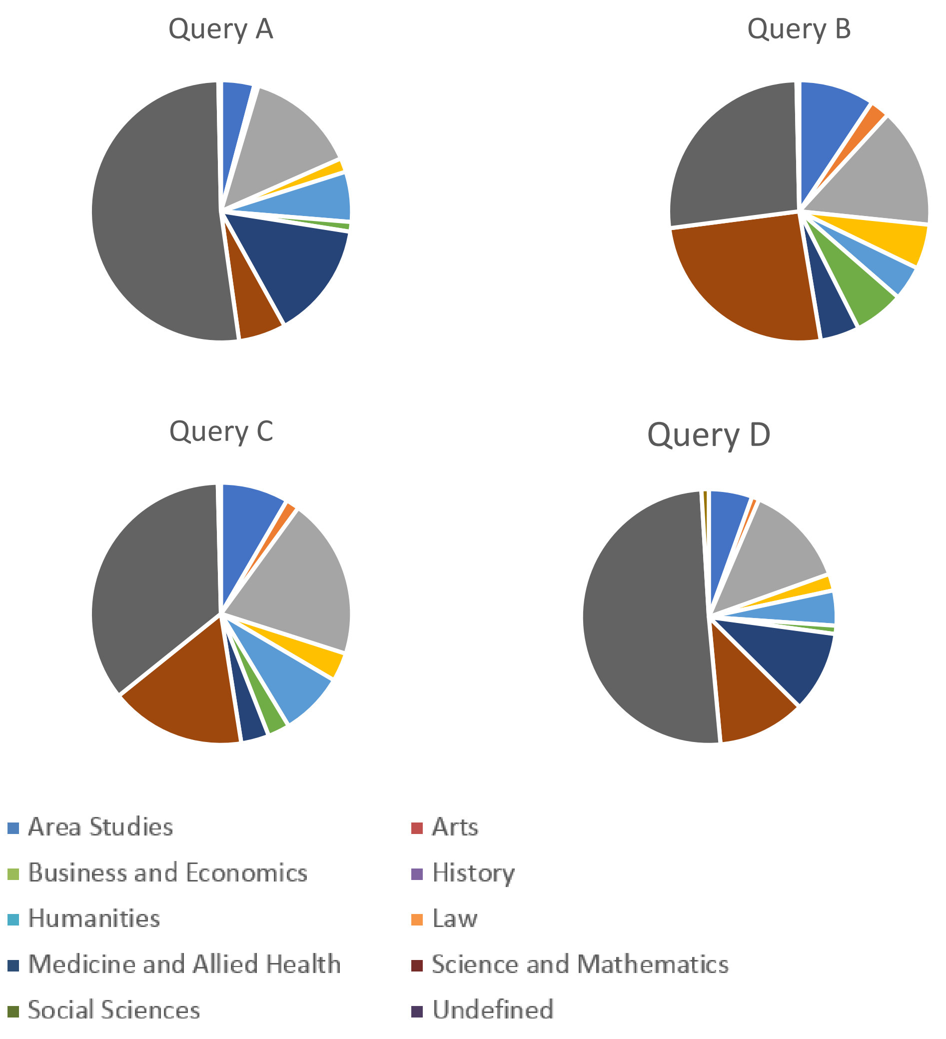
Figure 4: Top 20 journals shared by the publications by query



4.2.2.3 Subject group

In addition to the type of journals, further classification of a collection of papers under different subject groups potentially explains the multi-dimensionality of the subject matter (Juvan et al., 2005, Kevork & Vrechopoulos, 2009). For instance, in Figure 5, we observe social science is obviously the most dominant subject group for both SaW literature. The second most dominant subject group is business and economics followed by science and mathematics and so on. From this illustration, following information can be withdrawn from a glance: both SaW studies are deeply rooted in the area of social sciences which takes their social dimension into the account; their determinants, measures, indicators etc. with/without empirical evidence can be found in the in the papers from business and economics and science and mathematics subject groups; Well-being comparatively dominates in the subject area of medicine and allied health (literature from this area is discussed in detail in the later part of this paper on the types and dimensions of well-being related to different health outcomes.); similarly, area studies cover the demographic dimension of well-being. It is, however, not a key area for the literature of sustainability.

Figure 5: Subject-groups wise percentage of papers by query



4.2.2.4 Trend of publications

Many modern databases are particularly devoted to keeping the track of publications such as google scholar, ISI web of science, JSTOR, SCOPUS and so on, enabling the scholars to perform quick and broad browsing of literature (Hood & Wilson, 2003). Such tools make it possible to obtain indicators like a number of papers published in a particular discipline per year. Their expansions or contractions over time can indicate the interest of scholars in an area and the evolution of the subject (Adam, 2002, Casagrandi & Guariso, 2009).

In our analysis, Figure 6 illustrates the trend of the number of publication per year against each of the four queries from the year 1800 to 2012. The first article of query A (from 4,903 papers), related to well-being, appears in 1919 and number of publication remains trivial in this area until the 1970's. Thereafter, a huge influx of papers starts in the late 1970's from 30 papers per year which peaked at 311 papers in 2012. In contrast, papers related to sustainability in query B started much earlier. The first paper out of 57,681 of query B was published in 1800 which is the starting year for the entire dataset. This number reaches 50 papers per year in the next 100 years and steadily increase thereafter for another 50 years and is observed around 250 papers per year in 1950. After that, the number of scholarly articles grow by five folds over the next 5 decades and peaked in 2005 at 1304 papers. Articles related to both SaW in query C start emerging in late the 1970's and rockets over the next 40 years. Since query D is a fine subset of query C thus they exhibit similar trends with small numbers however.

Figure 6: Trend of publication by query

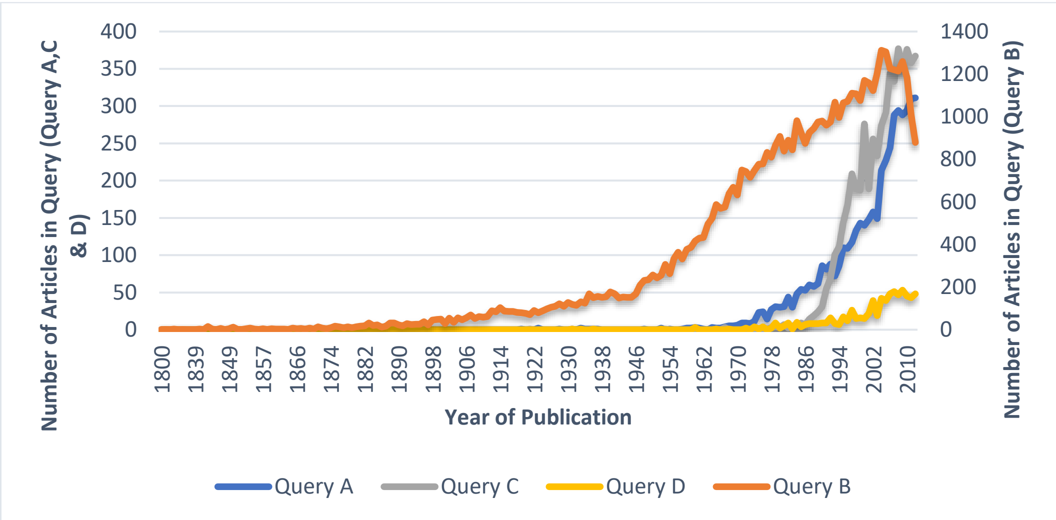
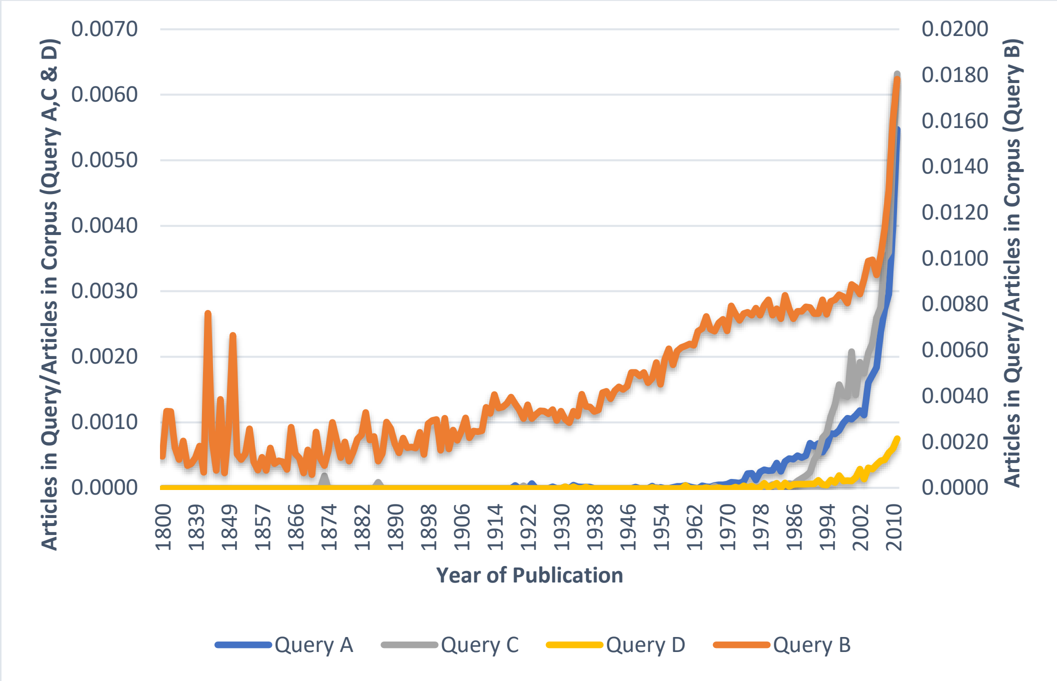


Figure 7 compares the number of papers per year in each query with the number of papers in the entire collection of the JSTOR database. This indicates the growing interest of scholars in both areas of SaW during last forty years compared to a range of all other areas covered in the 9.29 million articles on JSTOR dfr database.

Figure 7: Trend of publication by query vs total articles in the JSTOR database



4.2.2.5 Authors of publications and places

Another perspective of SaW knowledge is obtained by looking at the host country of the main author of an article in order to answer the key question "what countries are leading SaW agenda?" We select top 20 authors in each of the four queries based on their number of publications and find their country based on the place of affiliation given in the article at the time of publication.

Table 3 summarises the number of publication by 74 unique authors from 12 different countries who wrote 1869 papers[25] in total. Not unexpectedly, 9 of these countries are developed OECD countries. United State, perhaps not surprisingly, hosts scholars who published 61% of SaW literature in our sample of 68,817 articles. 29% of this literature is produced by people from Europe, Canada, and South Africa and the rest of them come from Australia, India and Botswana.

[25] Some papers are double counted because the four quires are over lapping and one paper may appear in the results of more than one queries. However, this double counting would not biased the dominance of a country for each separate query.

Table 3: List of 74 unique authors' host countries by number of papers by query

	Authors	Query A	Query B	Query C	Query D
Australia	5	39	29	34	9
Botswana	1	3	16	3	2
Canada	6	45	41	24	14
Finland	1	11	5	3	2
Germany	1	5	22	2	1
India	2	10	34	8	6
Norway	1	4	10	8	2
South Africa	5	27	85	17	9
Sweden	2	8	14	35	3
Switzerland	1	20	12	11	2
UK	3	24	42	31	10
USA	46	359	446	220	102
Total	**74**	**555**	**756**	**396**	**162**

From the above discussion, inter-relationship between SaW becomes clear from the similar range of frequently occurring keywords. Their research is published in a similar group of journals, they share the same subject groups by somewhat different proportions, they exhibit the similar trends in the historic number of publications, and finally, the major contribution in SaW literature is coming from developed OECD countries.

4.2.3 Analysis of literature at a micro level

4.2.3.1 Topic modelling: Latent Dirichlet Allocation (LDA)

Over a century of modern classic research has created a gigantic archive of academic publications which are becoming available online (Mimno, 2012). Collecting, understanding and summarising a large collection of documents has become increasingly important in many fields. However, it is often not possible for a human to comprehend enormous corpus under certain constraints such as time, money, capacity etc. (Chaney & Blei, 2012). Topic modelling offers a method for unsupervised learning of the topics contained in an enormous volume of text. Various algorithms for topic modelling have been proposed, and the results from these algorithms have been used to explore, summarize and visualize, the target document collections. A topic modelling algorithm, in general, takes a collection of documents as input. It then discovers a set of latent themes that are discussed in the collection and the degree to which each document exhibits those topics. Topic modelling can discover hidden topics in a collection of documents based on the assumption that a document about a certain topic would have particular words related to the topic in the article with higher frequency. For example, “storm” and “snow” will often appear in documents talking about the weather, whereas “banana” and “grape” will often appear in the documents discussing fruit. Current quantitative topic modelling methods are linked with latent semantic analysis (Deerwester, Dumais, Furnas, Landauer, & Harshman, 1990) and probabilistic latent semantic analysis (Hofmann, 1999). For a general introduction to topic models, see Steyvers & Griffiths (2007).

A topic, in topic modelling, is defined as a collection of words which occur together in a text corpus frequently and these words are related to a common subject. Although individual words carry some information, they are often not very meaningful as small groups of similar words. The same word could have significantly different connotations in different contexts. Statistical topic models such as LDA (Blei et al., 2003) attempt to capture groups of words that tend to co-occur while allowing words to appear in multiple groups. Using adjacent text, topic modelling can recognise words with similar meanings and distinguish between uses of words with multiple meanings. The concept of topic modelling with LDA in a large collection of documents was also originally introduced to model large corpora by discovering latent semantic topics. The underlying insight into LDA is the assumption that the words exhibit strong semantic information about the document itself. Thus, it is plausible to assume that documents on similar topics use a roughly similar set of words. Latent topics are therefore discovered by identifying a set of words in the corpus that are frequently occurring together within the documents.
LDA is a generative, probabilistic hierarchical Bayesian model that brings on topics from a collection of discrete data such as text documents in three steps (Blei et al., 2003):

1. Each document in the collection is modelled as a finite mixture of the underlying set of topics for that document based on Dirichlet distribution.

2. Each word in the document is linked with one topic on Dirichlet distribution.

3. Each topic is modelled as a multinomial distribution over words that are assigned to the sampled topic.

The number of topics in LDA is usually decided by perplexity which can be heuristically set in a range from 20 to 300 (Blei, 2012). Perplexity is normally applied to measure how a probability distribution fits the data. A lower perplexity specifies a model which can achieve enhanced generalization performance (Blei et al., 2003). Inferences from the topic models are independent of the content and language used in the data. They capture the statistical patterns of words used to present thematic content.

4.2.3.1.1 Related work

Since its introduction, LDA has been widely applied in many natural language processing, machine learning, information retrieval, and literature classification studies. McFarland et al. (2013) applied to study language differentiation in the field of sociology. Hassan & Haddawy (2015) used LDA to analyse knowledge flows of scientific literature in the field of energy. Bisgin, Liu, Fang, Xu, & Tong (2011) used LDA on the Food and Drug Administration approved drug labels to group drugs with similar characteristics. Griffiths & Steyvers (2004) applied LDA to find scientific topics in a collection of documents. Hall, Jurafsky, & Manning (2008) used LDA to study 12,500 papers of the Anthology. Yang, Torget, & Mihalcea (2011) applied LDA to model historic newspaper of the past 250 years.

In this paper we conducted textual analysis of SaW literature using LDA with Gibbs sampling implementation provided by the Machine Learning for Language Toolkit (MALLET)[26] applied by several recent studies including (J. M. Binder & Jennings, 2014, Bisgin et al., 2011, Eidelman, Boyd-Graber, & Resnik, 2012, Goldstone & Underwood, 2014, McFarland et al., 2013, Mimno & McCallum, 2011, Mimno, 2012, Yang et al., 2011).

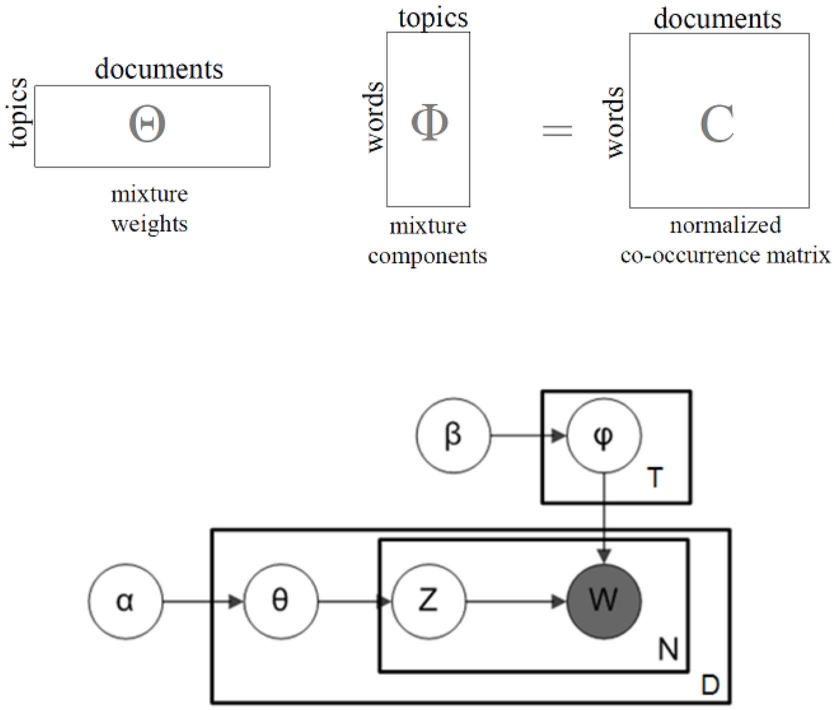
4.2.3.1.2 LDA: Notation and Terminology

Probabilistic generative models (e.g. LDA) with repeated sampling stages can conveniently be illustrated using plate notation (Buntine, 1994). Figure 8 shows the generic structure of topic modelling using LDA in which white and grey circles

[26] Machine Learning for Language Toolkit (MALLET) is a JAVA-based open-source toolkit that implements methods for document classification, cluster analysis, statistical natural language processing, information extraction, and other machine learning applications, including text topic modelling.

indicate observed and latent (unobserved) variables respectively. List of notations and their meaning in the LDA formula is given in Table 4.

Figure 8: Standard Topic Model



Source: Steyvers & Griffiths (2007) and Blei (2012)

Table 4: Notations in LDA formula

Notations	**Meaning**
d	Single document
D	Set of documents
w	Single word
W	Set of words
z	Single topic
Z	Set of topics
α	The hyper-parameter to generate θ from Dirichlet distribution
β	The hyper-parameter to generate φ from Dirichlet distribution
θ	A multinomial distribution over topics
φ	A multinomial distribution over words

$$P(w|d,\theta,\varphi) = \sum_{z\in T} P(w|z,\varphi_z)P(z|d,\theta_d) \tag{2.1}$$

$$P(Z|W,\Theta,\Phi) = \prod_{d\in D}\prod_{z\in T}\theta_{dz}^{ndz} \times \prod_{z\in T}\prod_{v\in V}\Phi_{zv}^{nzv} \tag{2.2}$$

For each document, a multinomial distribution θ_d over topics is sampled from the Dirichlet distribution with parameter α. Topic z_{di} is chosen form the topic distribution for each word w_{di} which is generated from a topic-specific multinomial distribution ϕz_{di}. The probability of generating a word w from a document d is given by the equation 2.1 and the likelihood of a document D is defined by the equation 2.2 where n_{dz} is the number of times which a topic has been associated with a document d, and n_{zv} is the number of times that a word w_v has been generated by a topic z. In its computations, LDA estimates its posterior distribution by computing inference (e.g., Gibbs sampling) or optimization (e.g. variation methods) (Blei et al., 2003, Griffiths & Steyvers, 2004, Steyvers & Griffiths, 2007).

The main variables of interested in the model are ϕ (the topics-words distribution) and θ (the topic distribution) for each document. Researchers have used different algorithms to extract topics from a text corpus and the Gibbs sampling is the most commonly used sampling algorithm for topic modelling (Blei, 2012, Ding, Rousseau, & Wolfram, 2014, Griffiths & Steyvers, 2004, Hassan & Haddawy, 2015, Steyvers & Griffiths, 2007). Gibbs Sampling constructs Markov chain Monte Carlo (MCMC) which refers to a set of random variables each dependent on the previous one. It simulates high-dimensional distribution by sampling on lower-dimensional subsets of variables where every subset is conditioned on the value of all others. Sampling is done sequentially and continued until the sampled values approximate the target distribution. Please see (Steyvers & Griffiths, 2007) for the arithmetic construct of Gibbs sampling and how ϕ and θ are approximated from posterior estimates of z.

4.2.3.2 Implementation of LDA and visualizing the results

In our study, we used MALLET version 2.0.8 (McCallum, 2002) which provides a highly scalable Java-based implementation of the Gibbs sampling algorithm from an R package called dfrtopics[27].

Exploring a text corpus with a topic model typically begins with the visualizing of the posterior topics through their per-topic term probabilities β. Researchers have used a number of methods to visualize and browse the latent semantic structure inherent in the corpus, and each method has certain advantages and disadvantages (J. M. Binder & Jennings, 2014, Chuang, Manning, & Heer,

[27] "drftopics" is an R package developed by Andrew Goldstone. The package provides an integrated solution to make and explore LDA topic models of the data available from JSTOR's Data for Research (DfR) service. It uses MALLET to run the models and ggplot2 and d3 graphics for visualizations. For further details please see https://github.com/agoldst/dfrtopics.

2012, Iwata, Yamada, & Ueda, 2008). One reason of the problem is that majority of the topic modelling research has focused on developing and improving topic modelling algorithms and very little attention has been given to improve the methods to presents results (Chaney & Blei, 2012).

Researchers have normally used browsers to evaluate modelling algorithms (Fortuna, Grobelnik, & Mladenic, 2005, Gardner et al., 2010). The key problem with these browsers is ease of use, available functionality and technical limitations. For example, some of them are entirely static are not very user-friendly to efficiently explore the corpus; while the other has technical problems like some emphasis on topics and give very little or no attention to documents and vice-versa (J. M. Binder & Jennings, 2014). Our research required a tool which enables smooth navigation between topics, words, and documents. We tested most of the available topic modelling visualization tools before selecting the dfr-browser [28] which sufficiently met our research needs.

4.2.3.2.1 Data pre-processing

In this part, we focus on the collection of text data of 761 papers related to SaW obtained from the results of Query D. This data is generated by optical character recognition (OCR) technology from over 9.29 million scholarly articles across a variety of disciplines provided generously by the JSTOR's DFR service. Before running topic modelling on our dataset, it is necessary to pre-process the data in order to eliminate a variety of possible errors in OCR generated data such as missing punctuation, uncertain separation of articles on the same page, meaningless combinations of words and letters from mathematical equations etc. Multistage data pre-processing was applied to reduce the errors which include the following steps:

- Isolate the comments and the source code identifiers
- Remove special characters from the text (e.g. de-hyphenating) and spelling correction

[28] DFR Model-browser interface is developed by Andrew Goldstone. The browser is a convenient tool visualize the multifaceted topic model with multiple views of the model. Please see the following for further details:

- http://agoldst.github.io/dfr-browser/
- https://github.com/agoldst/dfrtopics

- Split words based on common naming schemes
- Convert all text into the lower case and stem each word[29]
- Remove overly common words by using standard English stopword list

After pre-processing the data, LDA was applied to the corpus of 761 documents. We ran for 1000 Gibbs sampling iterations, the first 100 of which were used to optimize parameters (Griffiths & Steyvers, 2004). We allowed MALLET to use hyper-optimization for input parameters α and β, which are smoothing parameters for the topic model. One of the key challenges of unsupervised topic modelling is selecting the number of latent topics. For any given corpus, there is no incontrovertibly optimal choice for K (Wallach, Murray, Salakhutdinov, & Mimno, 2009). The choice of K is a trade-off between coarser topics (smaller K) and fine-grained topics (larger K). Setting K to exceedingly small values normally results in topics containing multiple concepts (for example, imagine a case of only a single topic which contains all of the concepts in the corpus), setting K to extremely large values, on the other hand, results in topics that are too fine to be meaningful and only reveal the characteristics of the data (McFarland et al., 2013). Our aim in this paper is to discover topics of medium level granularity so that we seek a reasonable value for K by simulating model on different values of K from 15 to 50. In our final model, we set K = 30 which suits our model the best. A comprehensive guide to replicate our study is given in the Appendix.

It is worth noting that, with different values of K, there were many zones of overlapping results, however, each of these trials revealed slightly different results. Since topic modelling algorithm is probabilistic therefore each time it is executed, it produces slightly different results. Therefore, pronouncements of topic modelling algorithms cannot be taken on faith, rather scholars should explore different ways of using them (Goldstone & Underwood, 2014). We used a range of different values before settling on the satisfactory one.

[29] We used snowball stemmer for stemming:

1. http://nlp.stanford.edu/software/
2. http://snowball.tartarus.org/

4.2.3.2.2 Results and findings

First of all, we are interested in automatically discovering general topics in SaW literature, the words they contain, and the portion of corpus they make. Figure 9 shows the topics in the form of circles with the most prominent words inside them arranged in a grid (any words with small weights are not included in the circles due to the size limit of a circle). The font size of a word reflects its weight within the topic. The thickness of a circle's borderline shows the proportion of a topic in the overall text corpus. In the list view given by Figure 10, topics are a list in the table form which helps to compare topics against each other. These topics are not only useful for model browsing and collecting quick overviews of the content and capture trends in the corpus. They are also useful in search of the articles related to the topic for closer reading (Please see Figure 11 for example).

In order to fully understand prominent topics in the corpus and prominent words in the topics, Figure 9 and Figure 10 must be considered pairwise. For example, topic 18 is the most prominent topic in the collection which makes 9.0% of the corpus with $\alpha = 3.99$. The most dominant words in this topic include social, human and development. There are only 4 early papers on this topic between 1930 and 1970 with a relevance of 5% to the topic. After 1970, there is a huge influx of paper related to the topic with a couple of peaks and trough in the following decades. Furthermore, Figure 11 entails topic papers related to the topic. Articles are sorted by relevance score of an article to the topic. It is worth noting that relevance function is biased toward longer documents with obvious high word counts related to the topic, however, it produces unbiased results with the topic. Ideally, a combination of ranking functions should be put into the practice but this functionality is not available in most of the topic modelling tools.

Figure 9: Topic model results (grid view)

Source: Generated with the data of OCR data of 761 papers related to SaW

A wave-like trend is significant for most of the topics with two crests (one at the beginning and the other in the middle with two troughs one in their middle and the other one at the end) explains the evolution of knowledge in the field of SaW. One of the plausible explanations is that the early study is setting a new research theme which is adopted by the others in the following years with some gap. Since the number of publications is monotonically increasing after the 1970s (as shown in Figure 6), A declining trend after the second peak is not because the research interest is decreasing but it explains the emergence of new research themes. Figure 12 which shows yearly[30] changes in the composition of topics

[30] Having a sense of changes over time in the compositions of the corpus in terms of topics is important in topic modelling. However, visualizing it altogether in one piece is challenging. In the yearly sub-view chart, all the time series of the topics are stacked on the top of each other in a steam-graph (Please see the following for the documentation: https://github.com/mbostock/d3/wiki/Stack-Layout). The height of each topic's steam shows the proportion of a topic in the corpus in a given year. The topics are re-arranged by a heuristic for making the graph less notched. Topics are distinguished by different colours. This view allows identifying prominent expansions and contractions of topics over time. Please note this chart might be misleading if the corpus has a lot of words in one year compared to the others. For example, topic 11 has an extraordinary long paper in 1936.

supports the argument that several new research themes emerged within the literature of SaW after the 1970s.

One of the key aims of topic modelling exercise on SaW literature is to find how sustainability and well-being are overlapping disciplines and what dimensions do they share. One way to address this within topic modelling is the application semantic similarity measure or topic entropy as the Jensen-Shannon distance (Hall et al., 2008, Mimno, 2012, Steyvers & Griffiths, 2007). R package "drftopics" has a built-in feature to measure topic similarity using multi-dimensional scaling based on principal coordinates analysis[31] in order to calculate the matrix of Jensen-Shannon distance between topics which are considered as a distribution over words into-two dimensional coordinates.

Figure 13 shows a scaled view of the topic model in which similar topics in the sense of having a similar distribution of words are located closer to each other. This clearly shows clusters of topics related to triple bottom-line of sustainability are placed in separate clusters. For examples, topics related to natural resources, economy and social dimensions are placed in the groups in the middle of the figure with different degree of distance. Topics related to health, family, children, justice, etc. are combined in the left block. Similarly, topics related to social dimensions of SaW (e.g. religion, income, life, satisfaction, gender, poverty, health, quality of life etc.) are seen overlapping and closer to other dimensions of SaW.

[31] Using the R multidimensional scaling function "cmdscale".

Figure 10: Topic model results (list view)

topic	1933—2013	top words	proportion of corpus
1		agricultural climate food change production agriculture farmers cattle soil livestock use changes crop global research	2.4%
2		children child family development early childhood families parents age developmental mothers health group social home	4.0%
3		urban rural land economic local areas development community growth new population migration poverty number cities	3.9%
4		identity social support psychological perceived ethnic age study research positive personal college high journal model	2.4%
5		data model variables effect effects results analysis income variable table measures models measure significant average	5.3%
6		forest communities community forestry forests management social timber pension indian amazon plan mexico years deforestation	1.3%
7		social journal positive life research work emotional psychological new stress personality studies psychology affect job	3.6%
8		development emotion effects growth brain during levels human developmental regulation exposure response cortisol biological behavior	2.6%
9		people way life become part time culture practice make made just often take power place	7.1%
10		development local project water projects planning government work activities management community international process impact people	3.1%
11		economic capital production trade natural market resources economy resource income energy consumption growth markets economics	3.6%
12		social life indicators satisfaction economic subjective people income happiness measures quality level index swb time	5.2%
13		women household men gender members capital households work social support groups group participation female poor	2.3%
14		religious religion spiritual faith church god religiosity protestant standards catholic spirituality christian group beliefs groups	1.2%
15		political new state social economic american national history university during government society press war civil	4.4%
16		business leadership management organizational employees work ethics servant corporate journal workers employee organization ethical organizations	2.2%
17		law note rights supra state legal id court public liability pollution states parens patriae courts	2.0%
18		social human development new environmental world environment approach nature knowledge global different sustainable cultural university	9.0%
19		conservation ecosystem water environmental ecological species coastal management areas river biodiversity tourism ecosystems marine economic	2.8%
20		housing neighborhood neighborhoods new households social behavioral residential high residents cluster efficacy performance likely percent	1.0%
21		health items scale measures factor study scales item scores measure used table validity sample analysis	4.3%
22		life patients quality health medical clinical care disease treatment patient data status time physical therapy	2.4%
23		countries development economic population world growth international country human developing social nations united capita gdp	3.3%
24		age high income social poverty birth school years percent education population employment status work elderly	3.5%
25		family children child families parents marriage fathers mothers father parental single parenting effects journal behavior	3.9%
26		poverty data research quality food com methods qualitative living study household participants respondents developing family	1.8%
27		policy health public research services care welfare programs policies program new benefits available provide review	5.1%
28		school education research students youth educational learning skills schools community young work teachers student helping	2.7%
29		health sex sexual mental south women people risk young use disease men study hiv public	2.3%
30		moral marketing qol black consumer life consumption need values journal satisfaction theory consumers needs personal	1.4%

Source: Generated with the data of OCR data of 761 papers related to SaW

Figure 11: Breakdown of a topic

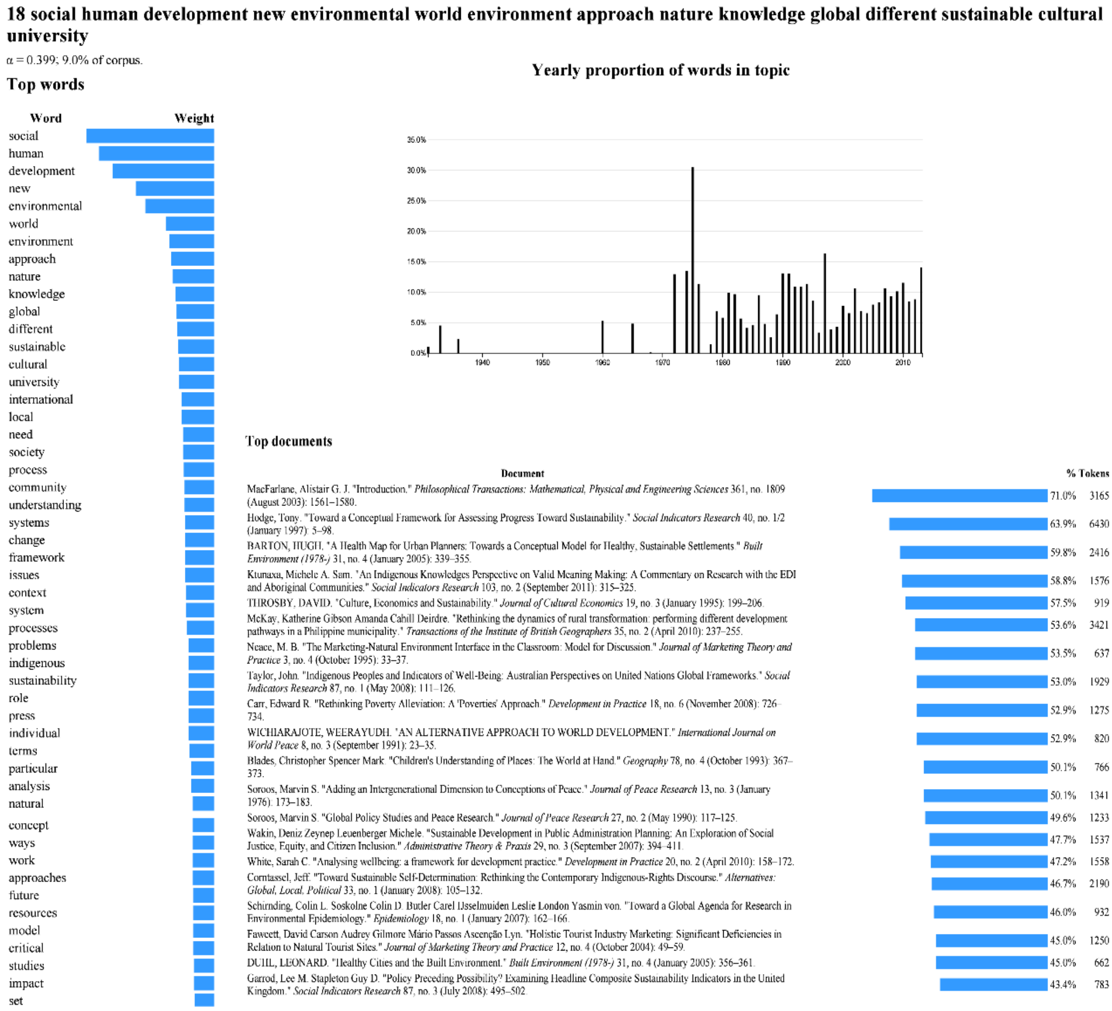
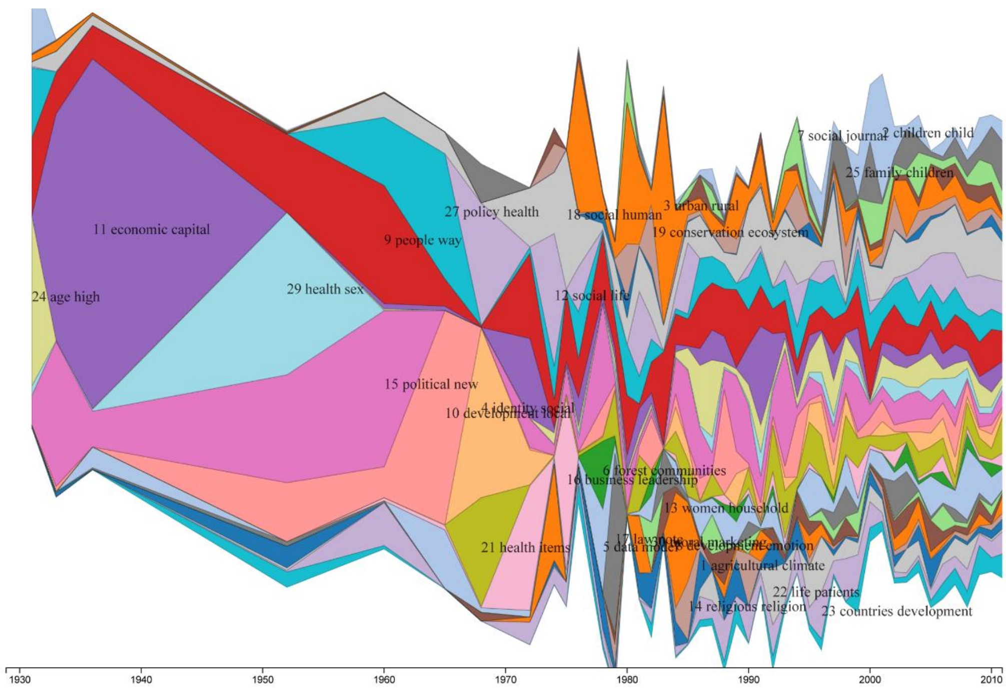
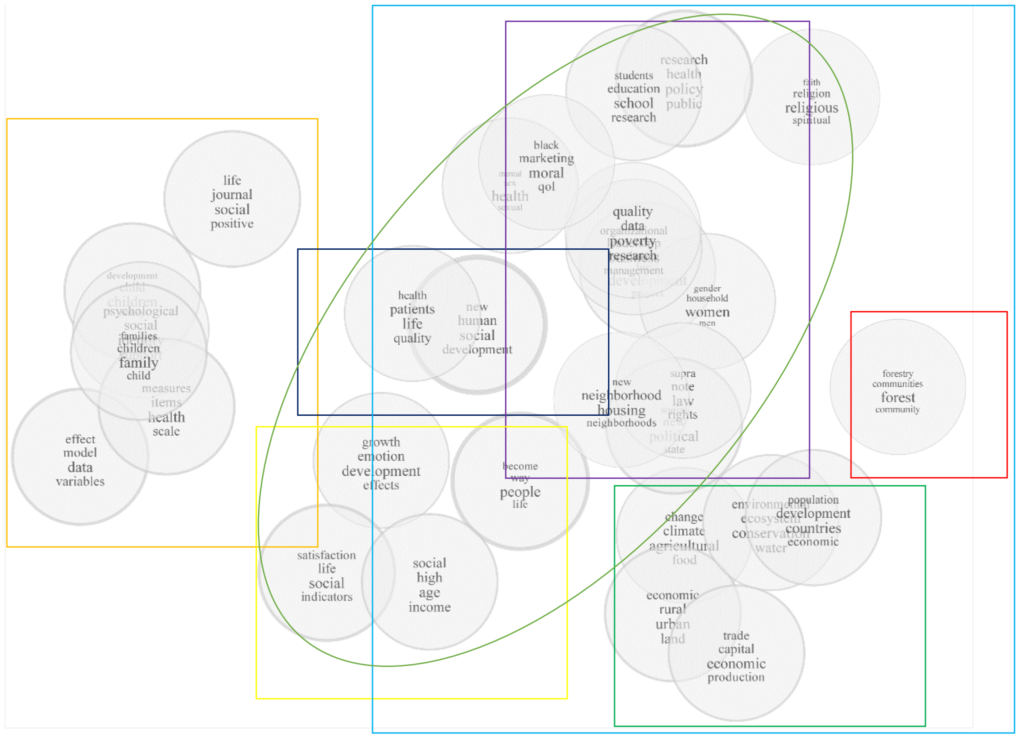


Figure 12: Topic model results (yearly sub-view)



Source: Generated with the data of OCR data of 761 papers related to SaW

__Figure 13: Topic model results (scaled view)__

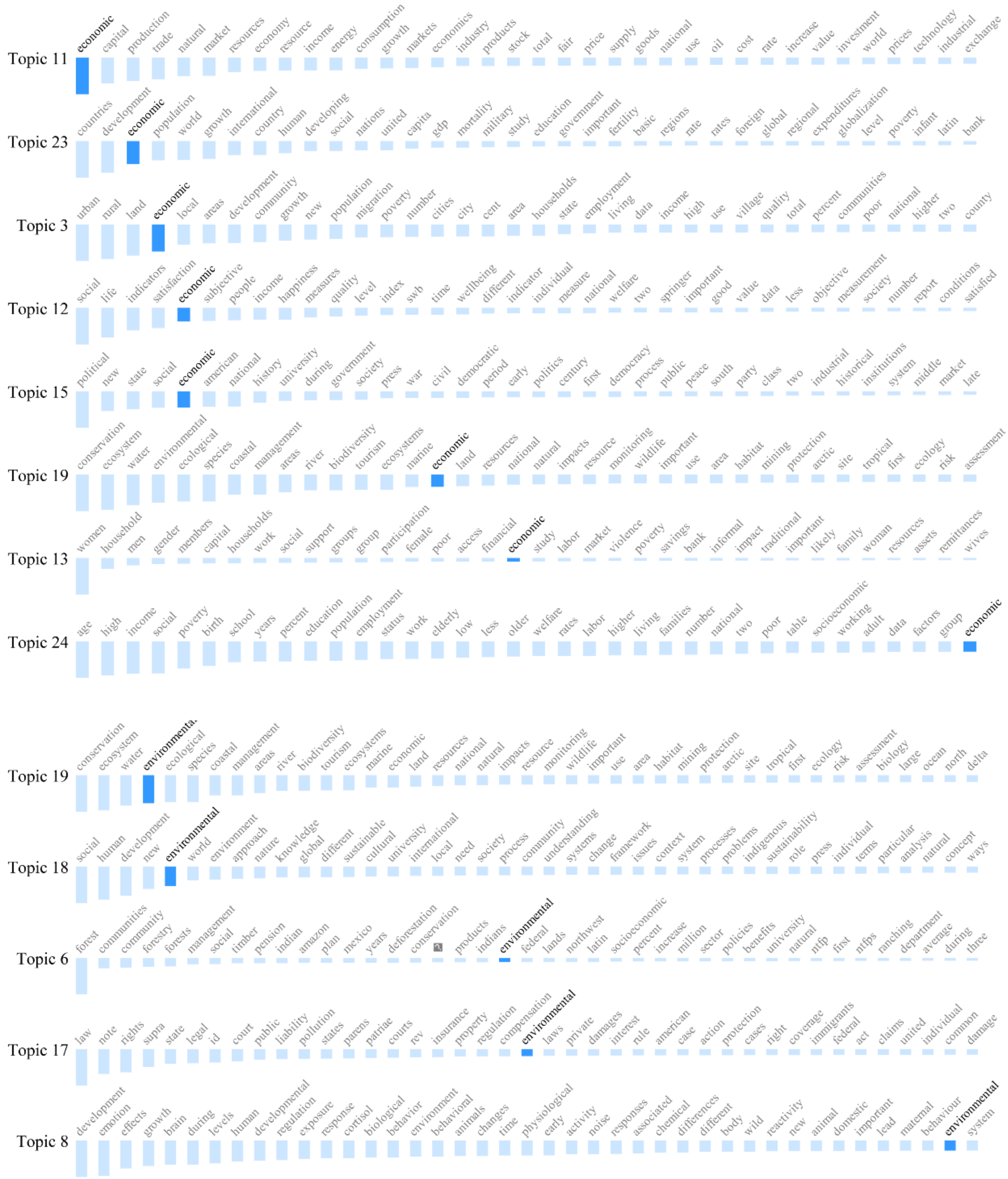


Source: Generated with the data of OCR data of 761 papers related to SaW

A closer view of semantic links between SaW literatures can be seen in the distribution of words within the topics and hypothesis of overlaps between SaW can be validated from the distribution of words across the topics. To elaborate this further, we cherry-picked words: economic, social and environmental (representing three pillars of sustainability) and plotted Figure 16. Each selected word is highlighted in blue. Each row displays the top words by topic. The height of the bars reflects the relative weight of a word within the topic which makes it possible to compare words against each other. The frequent occurrence of the same words across multiple topics indicates the overlaps between the SaW corpus. For instance, word "economic" appears in 8 different topics with variable weights across topics and each of this topics contains various terms related to human well-being. It is seen in the groups of dominant words in first five topics (i.e. topic 11, 23, 3, 12, 15), in middle-level group in the next two topics (i.e. topic 19 and 13) and among the least dominant group in topic 24. A closer look into these topics reveal that the set co-occurring words with terms "economic" from the dominant group include: capital, production, consumption, government, resource, supply, demand, population etc. from the middle-level group word economic co-occurs with: conservation, ecosystem, water environment, ecology etc. and from the least dominant words it co-occurs with family, children, school, poverty, children, etc. These results clearly identify all possible dimensions economics in different subjects.

Similar sort of behaviours is observed in the case of the other two words "environmental" and "social" with different trends and distributions however.

Figure 14: Topic model results (bar view)



Source: Generated with the data of OCR data of 761 papers related to SaW

In the overall results of the topic model of SaW literature (represented in Figure 9, Figure 13 and Figure 14) words related to SaW are well distributed over various topics. For example, distribution of words related three core dimensions of sustainable development (i.e. economic, environment, social) over topics is illustrated by Figure 14. To summarise these results into a framework, we conducted traditional literature reviews in the following part.

4.2.4 Linking sustainability and well-being: a conceptual framework

The relationship between inter-generational human well-being and the achievement of a sustainable future has a long and complex academic history. In his book 1848 book Principles of Political Economy, John Stuart Mill states:

"If the earth must lose that great portion of its pleasantness which it owes to things that the unlimited increase of wealth and population would extirpate from it, for the mere purpose of enabling it to support a larger, but not a better or a happier population, I sincerely hope, for the sake of posterity, that they will be content to be stationary, long before necessity compels them to it." Pg. 99

Later in 1910, Gifford Pinchot emphasized in his book The Fight for Conservation:
"The right of the present generation to use what it needs and all it needs of the natural resources now available [recognizing] equally our obligation so to use what we need that our descendants shall not be deprived of what they need." Pg. 80

Based on Pinchot's views, Brundtland commission report, in 1987, presented the more forceful concept of sustainable development to the global community as a new paradigm for economic expansion, environmental sustainability, and social viability. Brundtland Commission 1987 defines sustainable development as:
"Development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs."

Later in 1993, President Clinton endorsed the idea of sustainable development admitting: *"If we do not nurture our people and our planet through sustainable development, we will deepen conflict and waste the very wonders that make our efforts worth doing."*[32]

In 2000, sustainable development became an integral part of the United Nations' Millennium Development Goals and emerged as a shared vision of the governments

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[32] http://www.state.gov/p/io/potusunga/207375.htm

around the world. Recently, sustainable development is seen as a study of critical links between food, water, land, and energy in order to ensure that our current actions are consistent with our future aims (UN, 2012).

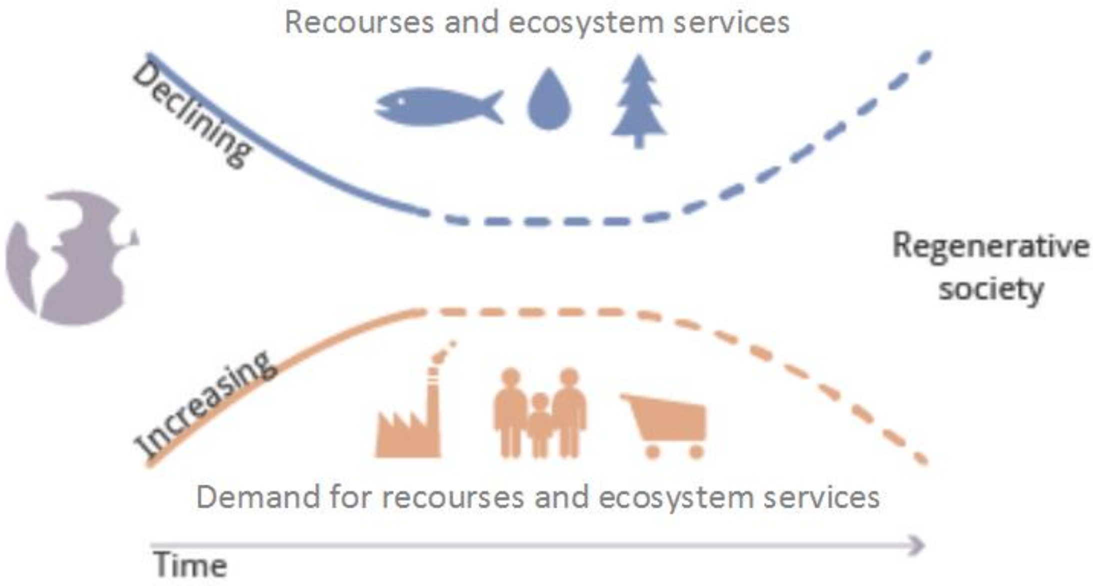
In each of the definitions stated above, half of the statement deals with the quality of life of present and future generation and the remaining half revolves around the environmental health of the planet earth and the availability of resources over time. It is generally accepted that economic growth coupled with higher consumption levels enhances human well-being[33], particularly in less developed countries (Brady, Kaya, & Beckfield, 2007), and improves the ecosystems which deliver valuable services to nourish, support and sustain life, and also improve quality of life in different ways (Agarwala, 2012, Ekins, Simon, Deutsch, Folke, & Groot, 2003, Liu et al., 2007, Roberts et al., 2013). This argument makes it clear that human well-being is the ultimate goal of all sustainability endeavours. However, keeping an acceptable balance between sustainability and well-being remains and open questions for further discussion in the later parts.

To explain the relationship between sustainability and well-being straightforwardly, the researchers have used funnel metaphor illustrated in Figure 15 (Broman, Holmberg, & Robört, 2000, Liu et al., 2007, Ny, MacDonald, Broman, Yamamoto, & Robért, 2006, Robèrt, 2000, Robèrt et al., 2007). With the rise of population, demand for ecosphere's life-supporting services e.g. clean air, water, food etc. is increasing whereas planet's capacity to provide these services is on the decline. For example, there are fewer forest and fish available today than they were a century ago (T. Jackson, Jager, & Stagl, 2004, Roberts et al., 2013, UN, 2012). Overharvesting, physical manipulation, and displacement of resources trigger losses of the productivity of natural resources (even if the yield may increase in short-run). Eventually, these vital resources require higher resource throughput i.e. fertilizers, pesticides etc. for the same amount of harvest or catch. Meanwhile, ecosystems are subject to higher concentration of substances which pollute them

[33] Scholars suggest conflicting views in this regard as well. For instance, (Firebaugh & Beck, 1994) suggest that economic development has increased life expectancy and reduced child mortality throughout the world. In contrast, Brady et al. (2007) argue that the effect of development on other well-being outcomes has decreased over time in developing countries, while Kubiszewski et al. (2013) and Roberts et al. (2013) suggest that many factors other than economic growth are also responsible to affect human well-being.

and causes climate change. It is as if we are moving in a funnel, more and more people are contributing to the funnel effect and we have lesser and lesser margin to manoeuvre overtime (Robèrt, 2000).

Figure 15: The funnel metaphor



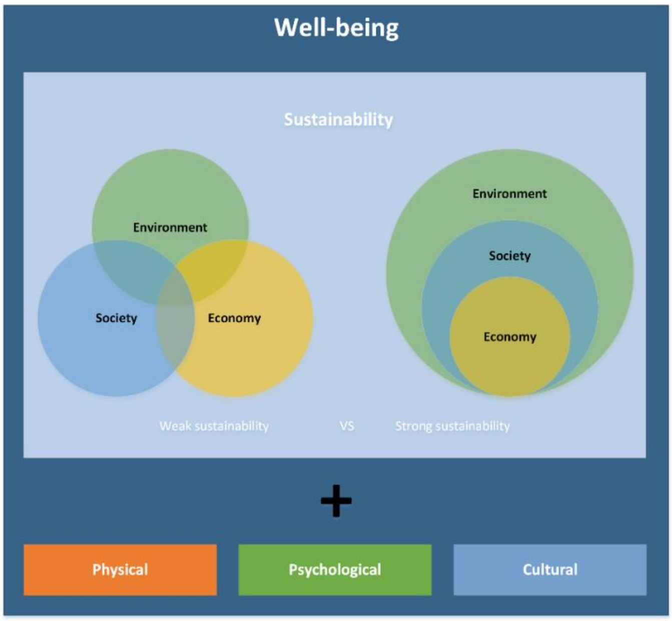
Source: Compiled from various sources

In conclusion, in one way or the other, every single person on the earth is affected by the pressures of the funnel effect. For the businesses and policymakers who are contributing to the funnels narrowing in relation to our conditions of prosperity and health, the walls of funnel will become more expensive for waste management, taxes, insurance, loans, loss of credibility, and market share losses etc. to those who are planning the future skilfully and taking those aspects into the account. Ideally, governments around the world, policies maker and businesses need to put their collective efforts together towards opening of the funnel in order to achieve the level of resilience where societies can prosper and thrive within the limits of nature (Lorek & Spangenberg, 2014, Robèrt, 2000, Robèrt et al., 2007)

Positioning SaW together is another philosophical debate. In his theoretical framework, (Kjell, 2011) places well-being within the sustainability process. He argues that well-being without considering sustainability adds the risk of impeding the sustainability process, therefore, well-being clarifies the aims of sustainability. While agreeing with the argument, a plethora of pre-existing qualitative and research quantitative research envisage well-being as a broader outcome of consumption of resources whereas sustainability is a concern as well as a constraint. For example, O'Brien (2008) explicitly states that "sustainable happiness is the pursuit of happiness that does not exploit other people, the environment or future generations" (p.290). Similarly, several other sustainability definitions (discussed in later in this paper) explicitly include the aspects of human well-being such as meeting needs (Brundtland et al., 1987), happiness (O'Brien, 2008) and "adequate quality of life" (Oskamp, 2000). We support the notion of sustainability positioned within ultimate human well-being.

From the above discussion, it becomes very clear that SaW are strongly interrelated subject matters. In real life, all human endeavours, in one way or the other, revolve around individual and/or collective welfare gain from activities ranging from meeting basic needs to utility maximization by having and/or consuming more and more material and non-material luxuries. Meanwhile, the given stock of resources to satisfy well-being needs are limited which pose sustainability challenge of irreversible losses from ever-increasing consumption. Moreover, distribution of resource across the globe and access and control over them adds further dimensions to SaW relationship. Figure 16 summarises high-level relationship between SaW which represents well-being a broader outcome and sustainability as a constraint. To elaborate on this relationship further details from multi-dimension perspectives, SaW are comprehensively discussed below.

Figure 16: Relationship between Sustainability and Well-being (simplified)



Source: Compiled from various sources

4.2.4.1 Multi-dimensional sustainability

A common starting point of sustainability argument is the famous definition of sustainable development given in Brundtland commission report in 1987 as:

"Development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs."

In a broader sense, positive sustainability is seen as the study of: the dynamic optimality, intergenerational neutrality, and interlinkages between economy and the environment which puts social equity within and between countries at the core of sustainable development (Endress *et al.*2014). However, the definitions of sustainable development are significantly different and highly inconsistent across disciplines (Lélé, 1991, Quiggin, 1997, Tisdell, 1988, 1993).

Neoclassic economic has dominated critical economic policy prescriptions including environmental issues and sustainable consumption. It typically evaluates policies based on their welfare outcome where welfare is normally equated with consumption (Safarzyńska, 2013). Sustainability theories of neoclassic economics have been criticised by new and emerging disciplines in economics, environmental sustainability, and behavioural studies. For instance, sustainable consumption in neoclassic economics is built around the notion of market equilibrium, utility maximization and preferences which is inadequate to guide policy prescriptions in the presence of dynamic preferences, uncertainties and complex socio-economic interactions (Akerlof & Shiller, 2010, Bergh & Kallis, 2009, M. Binder & Witt, 2011, Farmer & Foley, 2009, Gowdy, 2005, Ostrom, 2008, Safarzyńska, 2013).

While the others argue that ecological modernization concepts with emphasis on efficiency and innovation cannot guarantee to meet Brundtland's sustainability criteria. For instance, Lorek & Spangenberg (2014) argues that the concept of sustainability has been unfortunately weakened, misunderstood and misinterpreted by green economy/green growth theories since its formation 25 years ago. Nations are, therefore, hardly approaching it and current trends are moving in the opposite direction.

Under the following heading, we narrowed the definition of sustainable development further down in the field of economics by classifying and categorizing overlapping concepts.

4.2.4.2 Sustainability revisited

Although economic models of sustainable development limit the scope of objectives, they maintain internal consistency. The economic approach to sustainability is based on maximizing intertemporal welfare, where the constrained optimization problem includes system interlinkages and refrains from intertemporal discrimination (Endress *et al.*2014). In other words, sustainability in economic perspective rests on three pillars of inter-generational equity, interlinkages between environment and economy commonly referred as "environomy" and dynamic optimization (Stavins, Wagner, & Wagner, 2003).

Economists began with a modest specification of interlinkages, where production is taken as a function of natural resource extraction, capital, and labour. According to Endress, Pongkijvorasin, Roumasset, & Wada (2014, 1994) adding intergenerational equity in the function results in two main rules for sustainable and optimal growth: (i) extract natural resources in accordance with the principle for ***optimal resource management***; (ii) ***accumulate genuine savings*** guided by Ramsey condition for optimal savings and investment. Combination of these two principles provides a decomposition of the sum of natural capital and produced capital (used in GS) and optimal consumption path. This optimal path is sustainable even in the absence of sustainability constraint, which requires non-declining consumption over-time (J. C. V. Pezzey, 1997) or non-declining intertemporal welfare (K. Arrow et al., 2004). Optimal consumption continually rises and approaches the golden rule level (Endress & Roumasset, 1994).

These models can be extended further by including externalities such as pollution, greenhouse gas emission etc. under the same optimality condition of Ramsey equation and Pearce equation (Endress et al., 2014, Endress, Roumasset, & Zhou, 2005). Therefore, sustainable development does not require to abandon fundamental principles of economics as in the popularized approaches. Optimal growth theory for sustainable development only requires the combination of recognised economic principles indeed (Endress *et al.*2014).

4.2.4.3 Types of sustainability

The idea of sustainable development is tempting. It has emerged as the latest development catchword and became one of the key challenges of the century, however, the term itself has been repelling universally accepted interpretation (Clark, 2007, Dietz & Neumayer, 2007, Sachs, 2005). Though there is considerable political consensus on the notion of sustainability, the scientific consensus regarding fundamental question 'what to sustain?' (K. J. Arrow, Dasgupta, Goulder, Mumford, & Oleson, 2012, Dobson, 1996, Robert, Parris, & Leiserowitz, 2005, Stone, 2003) is still not reached (Brand, 2009). We must discriminate between a number of approaches in order to reach a substantive definition (Dietz & Neumayer, 2007). In economics, the debate over what sort of capital, i.e. natural capital, produced capital, human capital, social capital, ought to be preserved for current and future generations (K. J. Arrow et al., 2012, Costanza et al., 2007). At a conceptual level this is the choice between week sustainability and strong sustainability (J. Pezzey & Toman, 2002), a classic dispute between (Georgescu-Roegen, 1971, Solow, 1974) and (Georgescu-Roegen, 1971).

4.2.4.3.1 Weak sustainability

The concept of weak sustainability is rooted in the argument that natural capital and produced capital are similar and substitutable. The notion of weak sustainability emerged in the 1970s (Dietz & Neumayer, 2007) when neoclassic 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 on how much of it to consume and how much should be invested in produced capital for future consumption. The key question posed with these models was whether the optimal growth is sustainable in the sense of non-declining wellbeing which proved to be implausible in a model which includes non-renewable resource as a factor of production. It turns out 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 depletion of non-renewable resources should be reinvested in the produced capital. This could be considered as a general rule of weak sustainability that 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 negative (Hamilton, 1994).

Hartwick and Solow's models impute renewable and non-renewable resources in Cobb-Douglas production function 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 the productivity of natural capital at a higher rate than its depletion (Dietz & Neumayer, 2007).

In order to measure weak sustainability, we need to enter green accounting. In other words, we have to associate economic values to the reduction in the quantity of natural capital and to environmental degradation i.e. the economic value of damage to natural capital quality. 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; 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).

4.2.4.3.2 Strong sustainability

Proponents of strong sustainability view natural capital to a greater and lesser extent non-substitutable with other forms of capital. Following details explain this view. Natural capital broadly function under four categories: (i) it provides raw material for production and consumption; (ii) it assimilates waste associated with consumption and production; (iii) it provides eco-system services; (iv) it provides basic life support functions (Ekins et al., 2003, Pearce & Turner, 1990, Roberts et al., 2013). The fourth category, therefore, is not only a direct determinant of human welfare but also provides a foundation to first three categories. Substitution between first and second categories of natural capital and produced capital may be possible to some extent with high production efficiencies and advance waste management technologies. However, the basic life support feature of natural capital is certainly not substitutable and, therefore, is subjected to strong sustainability rule (Dietz & Neumayer, 2007, Roberts et al., 2013).

Since strong sustainability is a more rigid concept than weak sustainability, a number of rules have been suggested to operationalize it. Neumayer (2003) has identified two different schools of thoughts. One requires that the value of natural capital is preserved under the assumption of unlimited substitutability among different forms of capital. In the case of non-renewable resources, for instance, extraction should be compensated by the investment in renewable resources of the same value. The second school of thought requires that a subset of total natural capital should be preserved in physical terms so that its functions remain intact. This is so-called *critical natural capital* (CNC) (Brand, 2009, Ekins et al., 2003, Neumayer, 2003).

The debate between the proponents of weak sustainability and strong sustainability is continued till today. This research supports the contribution of (Ayres, 1999, Daly, 1997). These authors suggest that although there is a plenty of possibilities for substitutions and major breakthroughs, strong sustainability seems to be closer to the truth than unlimited substitution possibilities of weak sustainability. However, rather than selecting either of these two extreme positions of weak sustainability or strong sustainability, adopting a middle way between them is the most coherent election i.e. some degree of substitutability should be defined according to which some sustainable policies could be designed (Romero & Linares, 2014). Irrespective of the level of substitutability chosen, we need indicators to measure them. Frequently used indicators of strong sustainability are ecological footprints; material flow accounts; hybrid indicators etc.

4.2.4.4 Multi-dimensional well-being

Wellbeing is a set of objective and subjective components and in-built factors required for flourishing life positively. It is understood subjectively in psychology, however, in other disciplines it is comprised of a range of social indicators. Definition of well-being varies greatly across people, groups, and disciplines, and there is very little cross-match between them (Galloway et al., 2006, Roberts et al., 2013). For instance, (Huppert, Baylis, & Keverne, 2004), on page 1331, define wellbeing as *"a positive and sustainable state that allows individuals, groups or nations to thrive and flourish"*. According to Defra (2009), on page 119, wellbeing *"is understood to be a positive physical, social and mental state; it is not just the absence of pain, discomfort and incapacity. It requires that basic needs are met, that individuals have a sense of purpose, that they feel able to achieve important personal goals and participate in society. It is enhanced by conditions that include supportive personal relationships, strong and inclusive communities, good health, financial and personal security, rewarding employment, and a healthy and attractive environment."*

Wellbeing and happiness, two terms usually used as a pair in the literature, has been a focus of philosophy in history. However, there has been a rising interest in research on well-being reflected by the number of academic publication rising from less than 10 papers per year in the 1960s to over 2000 papers per year in the recent decade (M. Diener & McGavran, 2008). This rise in interest was partially initiated by Easterlin's essay in 1974 stating that per capita income in the United States doubled during the period of 1946 – 1974, however, individuals' happiness remained unchanged. Since then, a number of studies have been published addressing: What actually wellbeing is? What are its main contributors, and how should it be measured?

In general, the drive to increase human well-being by boosting consumption level negatively impact the ecosystem whereas protecting ecosystem reduces human wellbeing. It is, therefore, critical to understanding the main contributors of human wellbeing in order to explore new ways to enhance well-being without compromising environmental sustainability (Roberts et al., 2013). Therefore, this section is designed to: discuss recent developments related to different wellbeing concepts; explore key factors that contribute to it; and finally answer how wellbeing means differently to different groups.

Well-being is categorised into two broad categories: **objective well-being** and **subjective well-being** in different studies published in various disciplines such as psychology, welfare economics, ethics, ecological economics etc. (Abdallah, Thompson, & Marks, 2008, Cummins, 2012, Dodds, 1997, Galloway et al., 2006, Roberts et al., 2013, Waldron, 2010). The former broadly deals with material measures of wellbeing (summarized in Figure 17) such as income, employment, education etc. whereas subjective wellbeing focuses on people's self-reported happiness and satisfaction of life (Cummins, 2012, Gleisner, Llewellyn-Fowler, & McAlister, 2011, MacKerron, 2012, Roberts et al., 2013, Waldron, 2010).

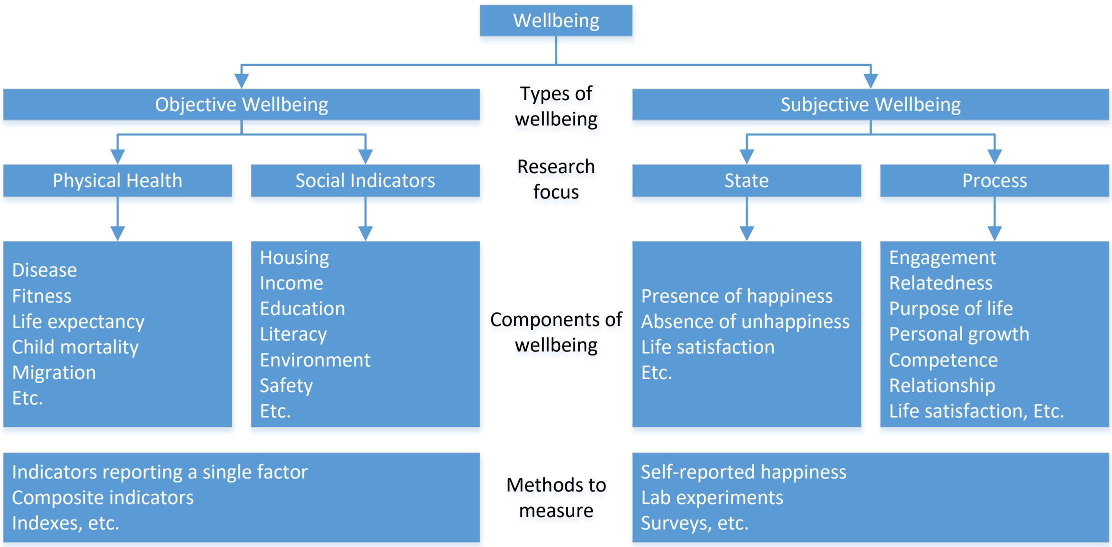
There is a range of contributor/satisfiers of wellbeing discussed in different areas of research. For instance, neoclassical economics sees wellbeing as an outcome of preferences satisfaction or utility maximization. In other words, one with higher income can have more goods and services leading to higher levels of satisfaction (T. Jackson et al., 2004, MacKerron, 2012). However, this approach has been lately criticised as income paradox which states that – once all of our needs are reasonably met, increase of happiness with an increase in income exhibits diminishing returns – several papers have found and confirmed this relationship (Cummins, 2012, Dodds, 1997, Easterlin, McVey, Switek, Sawangfa, & Zweig, 2010, Frey & Stutzer, 2002, Helliwell, 2003, Veenhoven, 1995). In a recent New Zealand focused study, (Sengupta, 2002) also found the same relationship for New Zealanders. Increase in happiness with an increase in an annual income from 10,000 NZD to 30,000 NZD is robust. This relationship becomes less responsive and tends to plateau beyond an average annual income of 65,000 NZD and increase in income beyond 125,000 NZD has an insignificant incremental effect on happiness.

In contrast, the relatively new fields – behavioural economics, ecological economics, welfare economics, happiness economics, neuroeconomics etc. – looks predominantly concerns with subjective well-being (Dodds, 1997, Frey & Stutzer, 2002, Jamison, 2008, Schwartz et al., 2002, Waldron, 2010). This approach studies certain feeling of the subject regarding her happiness, unhappiness, and satisfaction with life through different survey questions.

Happiness and life satisfaction have been used interchangeably in the literature, however, there is a clear distinction between them which poses major challenges in this type of studies. According to E. Diener, Ng, Harter, & Arora (2010), people tend to correlate life satisfaction with material prosperity when they answer how satisfied they are with their lives whereas they tend to correlate happiness with social prosperity once they have all the basic needs met. Therefore, most life satisfaction studies are actually related to income and standard of living.

Discipline of psychology treats well-being as a: **(i) state**, hedonistic theories of wellbeing, which articulate wellbeing as an attainment/presence of happiness or avoidance/absence of pain; or as a **(ii) process,** eudaimonic theory of well-being, which defines well-being in term of how a person is functioning in her life (Deci & Ryan, 2008, Konow & Earley, 2006, Mathers, 2013, Ryan & Deci, 2001).

Figure 17: Attributes of wellbeing



Source: Items down from (Rapley, 2003) and (Roberts et al., 2013)

4.2.4.4.1 How well-being differs across ethnicity and groups

The social context in which wellbeing is defined, referenced, perceived or applied is also a major issue. What is considered good varies greatly from person to person, society to society and religion to religion? It may also vary between different age groups and different sex within the same society. Applying a wellbeing assessment tools developed in one context to another context or another ethnicity is therefore likely to yield misleading results (Keith, 1996, 2001). A popular series of empirical research on individual wellbeing (i.e. General Social Surveys[34], Eurobarometer

[34] http://www3.norc.org/gss+website/

Surveys[35], World Values Surveys[36]) has been identifying the determinants of happiness among various population groups, which shows considerable degree of consensus, regardless of survey location, on determinants of happiness (other than financial determinants discussed earlier) which include cultural and religious affiliations, happiness of relatives and friends, strengths of social network, marital status (Brown & Tierney, 2009, Frey & Stutzer, 2002). Variation in such determinants group to group changes wellbeing perceptions accordingly.

Religious affiliation and beliefs play a vital role in defining psychological wellbeing patterns. (Dengah, 2014) suggests religious or secular lifestyle has a stronger impact on psychological well-being compared to socio-economic status. (Brown & Tierney, 2009) also recommend that religiosity demonstrates a strong correlation with wellbeing and happiness, in particular, among elderly people and women. They further argue that religion has a greater impact on the subjective well-being of men than women. People provide support to each other in faith-based communities in the face of vulnerabilities because religious people tend to rebound from divorce, illness, unemployment etc. because religion may foster higher expected utility hereafter (Azzi & Ehrenberg, 1975, Ellison, Gay, & Glass, 1989, Ellison, 1991).

Wellbeing related research in social psychology underpins a number of factors explaining why societies differ in terms of wellbeing. A culture shapes personality in a number of ways and vice-versa which influence an individual's realization of well-being (Tiberius, 2004). Key factors responsible for shaping personality are wealth and self-serving biases such as self-assessment, self-enhancement, self-criticism etc. (Biswas-Diener & Diener, 2001, E. Diener, Oishi, & Lucas, 2003). Wealthier nations score higher on human rights, equality, justice, democratic governance etc. therefore, positive relationship between wealth and wellbeing becomes obvious (Biswas-Diener & Diener, 2001, E. Diener et al., 2003). Self-serving biases are the deviations from the reality in which respondents tend to report overestimated or underestimated facts. For example, researchers have found East Asians weaker in self-enhancement (one of the serving bias in which one rates

[35] http://ec.europa.eu/public_opinion/index_en.htm
[36] http://www.worldvaluessurvey.org/

herself better compared to how she rates others) compared to American, whereas, they tend to have high self-criticism tendencies (Heine, Lehman, Markus, & Kitayama, 1999, Heine, Takata, & Lehman, 2000). E. Diener et al. (2003) found that European Americans tend to overestimate the number of anagrams they solved last week whereas, Asian American underestimate this number. Therefore, Dockery (2010) argues that indigenous culture should be viewed as a part of wellbeing enhancement tool, not as a part of the problem.

The strength of the social network is also seen as a determinant of wellbeing which may vary across groups (Ellison et al., 1989, Helliwell & Putnam2, 2004, Kettner, Köppl, & Stagl, 2012). However, various type of social networks may have a different correlation with well-being. For instance, Helliwell & Putnam2 (2004) found a robust and independent relationship between social capital and subjective well-being through family ties, relationship with neighbours, friends and relatives etc. However, no significant correlation has been proved between ethnic homogeneity in internet-based friendship network (e.g. Facebook) and subjective well-being (Seder & Oishi, 2009).

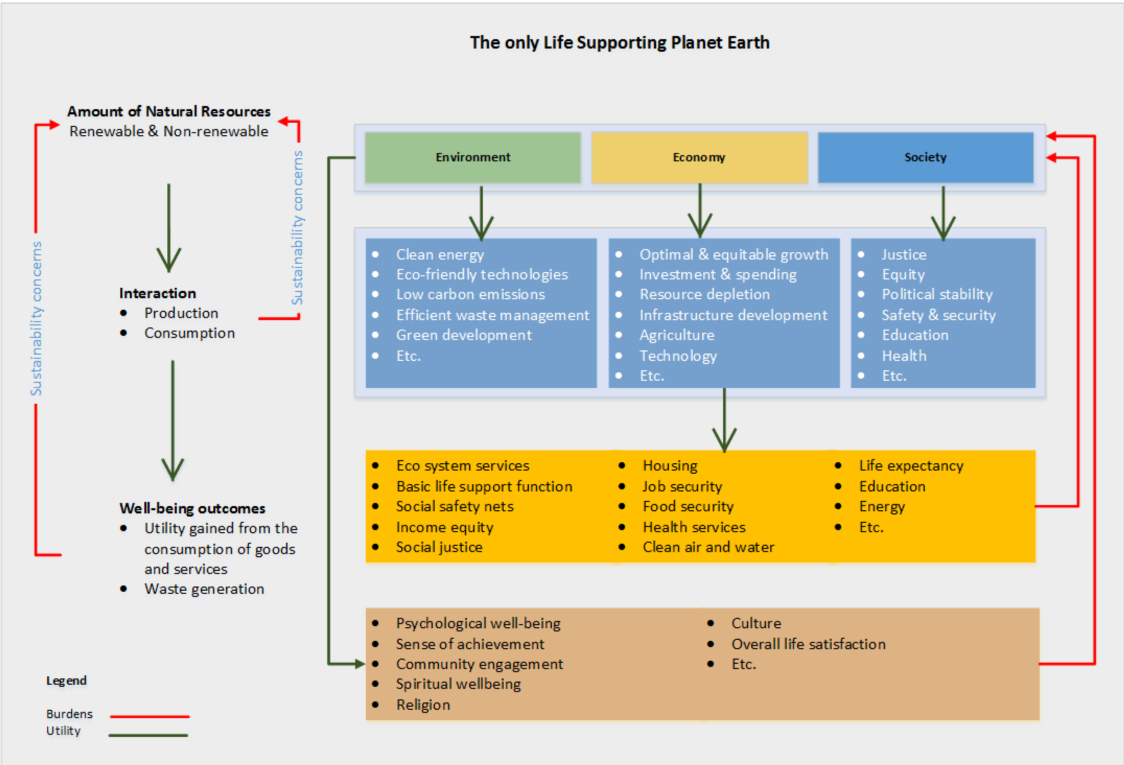
Similarly, ethnic diversity is also believed to affect well-being by influencing people's preferences and behaviours. In America, for example, housing price in a neighbourhood with more homogeneous minority population is higher (Li, 2014). In Keyna, primary school funding for the maintenance of the facility is strongly associated with ethnicity (Miguel & Gugerty, 2005). In the context of New Zealand, there are a number of aspects that contribute to the wellbeing of Māori but that may not apply to Pākehā. These include, for instance, manaaki (the ability to care for and in turn be cared for), oranga (wellbeing of human, physical, spiritual and environmental outcomes) and whanaungatanga (relatedness and obligation) (Durie, 2006, Harmsworth, 2002).

4.2.5 Consolidating SaW into a framework

From the above discussion, it becomes very clear that all forms of life on the earth are dependent upon the given amount of mutable and immutable natural resources. Depletion of these resources in the production of good and services required to support nourish and flourish the life, from satisfying basic human needs to enjoying infinite luxuries, and to further develop other forms of capital e.g. human capital and produced capital brings the sustainability concern into the question.

Meanwhile, the waste produced at each step of the life cycle of every single product from resource cultivation/extraction, transportation, processing, delivery, consumption and discarding the final waste exert further burdens on the environment and add value in the sustainability problem. This simple, intuitive and high-level SaW relationship is summarised in Figure 18.

Figure 18: Relationship between SaW (detailed)



Source: Compiled from various sources

4.2.6 Conclusion

In this paper, we presented sustainability and well-being as a fully integrated and unified subject matter by exploring semantic links between SaW literature available from JSTOR data for research. This relationship was further explored in the light of traditional literature review to establish how SaW are linked together which are finally summarised in a simple theoretical framework.

From this exercise, we are partly convinced with the notion of week sustainability that consumption of natural capital to develop human capital in present will lead to technological advancement in future to deal better with sustainability problem. Meanwhile, we also recognize the scientific facts of irreversible losses. For example, once a species is gone, it is gone forever.

Therefore, to us, sustaining long-term wellbeing is keeping a plausible balance between consumption of resources to thrive as a species and maintaining the planetary health without overstepping the irreversibility thresholds.

Global political and power structures, religion, culture, distribution, access, and control over natural resources adds a number of social dimensions in the SaW debate. Furthermore, the mechanisms to quantify the advancement of economies i.e. GDP define the pathways for countries to gain and maintain growth by higher consumption. Aggressive marketing campaigns by businesses define consumer behaviour which is normally invoking people towards over-consumption of good and services far beyond meeting the basic needs. On the other hand, the way natural resources are accounted using different approaches to allocate economic prices and discount rates play a critical role in defining how much should be consumed in a given timespan to maintain reasonable human well-being without putting planetary sustainability at risk.

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Chapter 5: Sustainability and wellbeing: a text analysis of New Zealand parliamentary debates, official year books, and ministerial documents

Mubashir Qasim

Abstract

Recent advances in the natural language processing and semantic analysis methods are enabling scholars in social sciences to analyse enormous text corpus as never done before. These techniques have not only minimized the margins of error arising from missing data from a traditionally conducted discourse analysis but they also permit reproducibility of research results by others. This paper analyses the use of the terms "sustainability" and "wellbeing" (SaW) in the text from parliamentary debates (Hansard), New Zealand Official Yearbooks (NZOYBs), and ministerial documents over a period of 125 years. We combined a number of text analysis methods to analyse our text data. The term "welfare" has existed in the NZOYBs and Hansard text corpus since the first year of our sample of data i.e. 1893, with a steadily increasing trend until the mid-1980s. The term "wellbeing" gained momentum in mid-1930s and it has been strongly linked with "sustainability" in the following decades. Our discourse analysis re-emphasizes the importance of The *Brundtland Report*: "Our common future" which acted as a catalyst to the global sustainable development movement in late 1980s. Before that, the term "sustainable" was predominantly used in the context of maintaining the levels of something and the term "welfare" was used with its standard meanings in isolation. However, post-1970, we see the term "sustainability" appearing with a sharply increasing trend. Sustainability and Wellbeing (SaW) started to appear in conjunction with each other in the following years. Our network analysis further shows how several SaW terms are connected with each other. Our findings also highlight that these networks differ significantly when the text corpus is separated for two main political parties of New Zealand, the Labour and the National. Substitution of the word resilience for sustainability can be seen to occur during the tenure of the previous National government – a trend we comment upon, somewhat negatively.

Keywords: Sustainable development, wellbeing, text analysis, resilience, parliamentary debates, Hansard.

JEL classifications: C80, I31, N00, Q01, Q56

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5.1 Introduction

Sustainability and Wellbeing (referred to henceforth as a unified subject matter descriptor, SaW[37]) is an interdisciplinary, interrelated, and complex subject matter which underpins a wide range of socio-economic factors to attain an equitable quality of life intergenerationally without going past the planetary boundaries to replenish itself (Greasley et al., 2014, Qasim & Grimes, 2018, Qasim, Oxley, & McLaughlin, 2018, Qasim, 2018). In generic economic terms, having more or consuming more goods and services is directly associated with higher levels of human wellbeing. On the other hand, everything we require to survive and thrive (e.g. breathable air, drinkable water, food etc.) depends on the environment directly or indirectly including the production of these goods and services; and waste assimilation generated during the production, consumption and transportation processes (Marsh, 1864). The notion of sustainability focuses on a straight forward and historically well-established fact that environmental services exploited to satisfy human needs should not exceed earth's carrying capacity over the long-run. Such alignment of sustainability and human wellbeing (SaW) gives birth to a unified subject matter sustainable wellbeing (SaW).

Considerable effort has been expended in order to consolidate a wide range of SaW definitions to set agreeable goals for governments, organizations and businesses around the globe since late 1980s. Nevertheless, this debate is yet to be concluded (Qasim, 2017). For instance, researchers have used the word *"sustainability"* to describe a wide range of environmental, social and economic issues; and word "*wellbeing"* for mental, social, physical and psychological health related issues. Usage of these terms in a broad range of scenarios has lead to one of the most interesting recent economic, social and political research streams within a burgeoning SaW literature. While politically ubiquitous, they can also be analytically ambiguous (Amsler, 2009). Sustainability means different things to different people (Jickling, 2001)[38]. Unlike academic scholars, law makers and government organizations tend to be reluctant to utilise unclear concepts and

[37] Historically sustainability and well-being has evolved as independent but inter-related subjects. However, realization of the fact that the ultimate aim of all sustainability (or sustainable development) endeavors is to achieve higher quality of life for everyone equitably (e.g. supporting the disadvantaged at higher priority) has turned them into a unified subject matter see Qasim (2017) and (Qasim, 2018) for details.

[38] "Sustainability doesn't mean anything real to consumers. Too often, it brings to mind technical issues or seemingly insurmountable environmental challenges." Williams (2016)

catchwords (like sustainability to avoid language disconnect). Instead, they would typically rather expect to have precise terms terminology when formulating specific policies or laws. Nowadays, it is also commonly believed among policy makers that some prefer to talk about "sustainability" without using the actual word itself. In this paper, we tested to the extent to which these perceptions are factual in the context of New Zealand using an enormous text corpus of the literal words of truth.

In this study we analysed the presence of terms *"sustainability"* and *"wellbeing"* in New Zealand parliamentary debates and policy documents to address the key question of how and when we adopted "*sustainability"* and "*wellbeing"* in our language. We analysed text corpus of New Zealand parliamentary debates transcripts (Hansard) and NZ Official Year Books (NZOYBs) over a period of 125 years. These data are also combined with the text of annual reports from the Ministry of Business Innovation and Employment (MBIE), Ministry for the Environment (MFE), Ministry of Primary Industries (MPI) and NZ Treasury for the maximum periods available[39]. For the text analysis we applied various text analysis methods including, normalised word frequencies per year, to extract the historic trends in the evolution of SaW terms and applied methods for example, bigram networks of highly correlated terms, to extract how they are linked. We further explain how these trends and networks are affected by the political party in power.

Our main results show that terms "welfare" has a long history in New Zealand as it appeared from the very first year in our data i.e. 1893 with a steadily increasing trend until mid-1980s. After which the decline in the use of "welfare" was off-set by sharply increasing trends in term "sustainability". Our pre and post 1970 bigram network analysis shows the emergence of *"sustainability"* in the context of *sustainable development* in the later part only. Reasons for these changes include change in political parties, global policies, and most importantly influence from sustainability research. We also observe a recent tendency to replace the word resilience for sustainability and comment on the usefulness or otherwise of this trend.

[39] See data section for data coverage of ministerial documents.

5.2 Background

The economy of New Zealand has evolved through several phases of economic development led by both different shades of government and individuals. There has not been any single solution to New Zealand's economic problems and governments adopted often quite radical measures over the years. For instance, Vogel's programme for public works, Muldoon's "Think Big" and tighter regulations, Douglas's privatisation and deregulation, and recently Adhern's reinvention of social policies and wellbeing centric budget. All of these changes have redefined notions of sustainability and wellbeing according to governments' implicit or explicit objective functions. Without going into details at a granular level, this section aims to briefly discuss the historic evolution of the New Zealand economy by arranging time into five major stages of development (shown in Table 1.) to help focus readers onto the varying contexts of the use of SaW terms. A detailed timeline of key events in the economic history of New Zealand is provided in the Appendix.

Table 1: Stages of New Zealand economic development

Stage	Period	SaW Focus
1	1860s – 1914	Liberal-focused economy mainly driven by individuals, farming, mining and quarrying of natural resources.
2	1915 – 1934	Period of struggles through war, epidemic, and economic depression.
3	1935 – 1966	Big government with stronger central control of the economy, partial industrialisation, welfare state, social housing.
4	1967 – 2016	Neo-liberalism, privatisation, public enterprises sell-offs on a large scale, implementation of the NZ experiment.
5	2017 onwards	Reinvention of social policies and wellbeing focused policies.

5.2.1 Stage 1: 1860s – 1914

The economic system of New Zealand was largely shaped by individuals' desire to improve their personal wellbeing, since the mid-nineteenth century from the arrival of British settlers and immigrants from other parts of the world. However, the government also played a vital role in its liberal manners as a facilitator. Key focus of economic activity during this period was farming and the trade of cheap raw material from natural resources which was highly demanded in the world e.g. seals, whales, flax, trees etc. Mining and quarrying of natural resources became a major driver of the economy after the discovery of gold. While the farming sector was limited by access to land and wars over land in the 1860s. The Gold rush attracted more immigrants to New Zealand than did the any other commodity exploited before (Briggs, 2003, Hawke, 1977).

The Gold rush was over by the 1870s and it was no longer a permanent economic activity. Agriculture once again dominated the exports from New Zealand where most went to Britain. Julius Vogel, the treasurer under the administration of William Fox (then prime minister of New Zealand), launched a massive drive for public works and immigration[40]. Heavy borrowing from overseas was invested to develop better transport infrastructure particularly in settled dairying areas. It improved the access to many areas of the country and further accelerated pasture-based farming. The use of refrigeration in exports made it possible to export frozen meat, butter, and cheese by the 1890s. The country was able to produce these products at very competitive prices because of the year-round pastural farming and availability of grass. With soaring export prices from the mid 1890s, New Zealand was one of the highest GDP per capita countries in the world (Briggs, 2003).

5.2.2 Stage 2: 1915 – 1934

The period between 1914 – 1934 was a miserable time of unique failure for the New Zealand economy. This period saw with unemployment rates, riots, repressive policies and falling incomes. Many of these crises were external in terms of origin and, thus, were out of control for New Zealanders. The country experienced various crises including people displaced during the first world war, loss of lives, and the epidemic of influenza in 1918. This was worsened by unprecedented unemployment rates, declines in real wages and rise in prices and government debt. The value of New Zealand exports fell by 40% following (and even preceding) the Wall Street crash in 1929. Average incomes per capita in real terms fell by about 20% in 1930 (Hawke, 1977). In 1932, Britain retreated from the free trade “Ottawa Agreement”.

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[40] This is referred to as “Vogel Programme”. Vogel’s vision was to extensively develop the economy through immigration, public works and infrastructure development. Without going into the pros cons of the state controlled development from efficiency perspective, this programme, without a doubt was a prominent example of government led development in the 19th century in New Zealand (Hawke, 1977).

5.2.3 Stage 3: 1935 – 1966

New Zealand started to recover with a rise in exports as the US and Europe recovered from recessions. In 1935, The Labour Government was elected for the first time and country started to move towards a more state-controlled economy from individually controlled state with the government spending being an important instrument of economic policy [41] . The Labour government implemented a comprehensive system of social security in 1938 and introduced family benefits in 1946 to financially support parents with limited incomes. Such welfare-oriented policies reflected a common expectation that the state could deliver "cradle-to-the-grave" protection to its citizens against economic shocks (Condliffe, 1960, Sutch, 1942). This government was also determined to provide full-employment to the labour force and maintain it by insulating it from international shocks. Despite an ambitious government drive, full employment was not achieved until Second World War absorbed most of the labour force.

Moreover, the need for industrialisation became imminent as agriculture and farming could not provide enough jobs to accommodate the full labour force. Existing industries were promoted and new were established to create more jobs. As a result of a massive drive for nationalisation, the government had widespread ownership in education, health, banking, insurance, transport, energy and other utilities. Real GDP per capita grew at a much faster rate than before with the growth in manufacturing sector and with higher production efficiency. Value added products from pulp, paper, steel, and oil industries started to contribute to national exports, however primary products still accounted for most of the exports by the 1960s. New Zealand became one of the richest countries in OECD during this period in terms of real GDP per capita (Briggs, 2003).

5.2.4 Stage 4: 1967 – 2016

Wool, one of the major export products from New Zealand started to lose its value due to, in part, competition with synthetic fibres. The price of wool collapsed, and the Wool Commission ended its role of buying and selling to stabilise the price.

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[41] One of the motivations to gain government control over the state was to insulate economy from the depressions caused by external shocks. Insulation, however, was a complex issue. It was considered mainly in the context of providing stable prices to the dairy farmers irrespective of export prices. In doing so, over ambitious policies of the Labour government led to the exchange crises and the economy was unable to finance imports.

Britain joined the European Economic Community (EEC)[42] in 1973 which imposed quota limits on New Zealand's meat and dairy exports. This was followed by additional external shocks due to the sharply rising oil prices following Israel-Arab war in 1973 and in 1978 because of the revolution in Iran. Following these events, foreign debt rose from 11% of GDP in 1974 to 95% by 1984. Public debt increased from 5% to 32% of GDP and inflation rates remained in double digits during this period (Evans et al., 1996). New Zealand lost its place of being one of the richest OECD country in 1960s and became one of the poorest in 1990s.

Despite these shocks, interestingly, real GDP per capita continued to grow steadily because of slower (or even negative) population growth rate. The New Zealand dollar was widely believed to be overvalued during early 1980s and the country experienced a massive outflow of foreign exchange during the elections of 1984. This rapid outflow led to country's worst foreign exchange crises as the central bank ceased the conversion of the New Zealand dollar into foreign currencies. This provoked a unique constitutional crises for the new government. Following these crises New Zealand embarked on one of the most comprehensive and coherent economy-wide reforms[43] between 1984 and 1996.

It is generally agreed that by the end of 1990s, the country emerged as a more liberal, diversified, and low inflation economy. With open and competitive markets in the 21st century, the economy stood out in international comparisons in terms of for example, ease of doing business. New Zealand became the first OECD country to maintain long-term fiscal surplus in recent years. Excluding the short periods of recessions, around 2008-09 global financial crises, the country managed to reduce unemployment levels to record lows (RBNZ, 2007).

5.2.5 Stage 5: 2017 onwards

New Zealand was an early pioneer of welfare-oriented social policies ranging from womens' right to vote in 1893, supporting families with limited incomes, unemployment support, old age benefits etc., (Evans et al., 1996). The Labour Party

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[42] EEC is now known as European Union (EU).

[43] Henderson (1995), an OECD expert, views these reforms as called "one of the most notable episodes of liberalization that history has to offer." These reforms included massive drive for privatization restoring individuals' control over the economy. This period is of reforms, therefore, is also referred to as the period of neo-liberalism in New Zealand. According to Evans et al. (1996) these series of supply side reforms successfully improved the performance of a poor economy however Dalziel (2002) argues this programme did not achieve the objectives expected from it.

formed a government in 2017 (although it wasn't the largest party) with an agenda to re-invent social policies. The newly elected government appears committed to deliver high levels of wellbeing while ensuring maximum environmental sustainability[44]. Some of the SaW policies include exclusive reporting against a range of indicators in future budgets and a 2019 budget which is being dubbed "the wellbeing budget", which is being designed to focus on some SaW ideas that go beyond traditional economic performance measures. To create this budget Treasury appears to be, rebranding it's "Living Standard Framework" (LSF) for more specific decision making related to intergenerational wellbeing and for setting future priorities (Treasury, 2018a, 2018b)[45].

5.3 Data and methods

The text data used in this study have been extracted from multiple sources summarised in Table 2 and processed using a range of advanced text analysis methods[46] discussed later in this section. Data analysis is conducted using the R programming language. There is plethora of R libraries to conduct end-to-end text analysis and plotting tools to report the results.

Table 2: Data type, sources, and coverage

Type	Coverage	Source
1. Parliamentary debates	1893 – 2017	New Zealand Hansard database website (and third-party websites)
2. Annual NZ official yearbooks	1893 – 2010	Stat NZ website Yearbook collection: 1893–2012
3. NZ Treasury annual reports	1999 – 2017	The Treasury New Zealand website
4. MFE annual reports	1999 – 2016	Ministry for Environment (MFE) website
5. MPI annual reports	2010/11 – 2015/16	Ministry for Primary Industries (MPI) website
6. MBIE annual reports	2012/13 – 2016/17	Ministry of Business, Innovation and Employment (MBIE) website

Source URLs:

1. https://www.parliament.nz/en/pb/hansard-debates/rhr/
2. http://archive.stats.govt.nz/browse_for_stats/snapshots-of-nz/digital-yearbook-collection.aspx
3. https://treasury.govt.nz/publications/corporate-documents/annual-reports
4. http://www.mfe.govt.nz/publication-search
5. https://www.mpi.govt.nz/about-us/corporate-publications/
6. https://www.mbie.govt.nz/publications-research/publications

[44] https://www.budget.govt.nz/budget/2018/economic-fiscal-outlook/budget-2019-focus-on-wellbeing.htm accessed on 12th December 2019.

[45] Theoretical foundation of the Treasury's LSF is grounded in the principles Genuine Savings and weak sustainability (Qasim, Oxley, & McLaughlin, 2018). It mainly deals with maintaining four different capitals i.e. natural capita, social capital, human capita and physical and financial capital. Stocks of these capitals represent the total national wealth.

[46] See the following papers as examples of for commonly used corpus analysis methods in political economics: Benoit et al. (2016), Lucas et al. (2015), Fabbrizzi et al. (2016), Rheault et al. (2016), Willis (2017).

Hansard data contain records of what is said in the New Zealand parliament debates and individual speeches or statements delivered by the parliamentarians. Hansard data are available in three types of digital formats derived from various eras of publishing technologies. The first 402 volumes, from 1893 to 1987 (volumes 80 – 482) are simple scans of original hardback copies from the University of California. These volumes are digitized by Google using optical character recognition (OCR) technology and are hosted on a third-party digital library called the HathiTrust[47]. The second group of volumes, from 1987 to 2002 (volumes 483 – 605), are PDF files generated by word processing software. These volumes are available through a public Google drive folder[48]. The third group of volumes from 2003 onwards are available in both HTML and PDF formats on the Hansard New Zealand website itself.

The New Zealand Official Yearbooks (NZOYBs) are considered as the comprehensive documents of the New Zealand economy from 1893 to 2012 from a statistical viewpoint. Annual NZOYBs were downloaded from Statistics NZ official website[49] in HTML format (except 2010 version which is available in PDF format). Similarly, annual reports from the New Zealand Treasury and other Ministries noted in Table 2, were retrieved from their official websites in PDF format.

5.3.1 Data pre-processing

We transformed data from various formats to a standardized plain text format. It is necessary to pre-process the data before running any analysis on a text corpus, in order to eliminate a variety of possible errors in OCR generated data such as missing punctuation, uncertain separation of articles on the same page, meaningless combinations of words and letters from mathematical equations etc. Multi-stage data pre-processing was applied to reduce errors which involves the following steps:

- Isolate the comments and the source code identifiers.

[47] Historic Hansard volumes of NZ parliamentary debates from 1854 to 1987 are hosted on HathiTrust which can be accessed from the following url: https://babel.hathitrust.org/cgi/mb?a=listis&c=71329709

[48] Updated working link to the google drive folders can be found on the Hansard website: https://www.parliament.nz/en/pb/hansard-debates/historical-hansard/

[49] http://archive.stats.govt.nz/browse_for_stats/snapshots-of-nz/digital-yearbook-collection.aspx

- Remove special characters from the text (e.g. de-hyphenating) and spelling correction (e.g. “sustainably” to “sustainable” and “resilient” to “resilience” etc.).
- Split words based on common naming schemes.
- Convert all text into the lower case.
- Merge similar words e.g. sustainable and sustainability; welfare’s and welfare; happily, happiness, and happy; sustained, sustaining, and sustains[50].

After pre-processing, we filtered out everything from the text corpus except the desired SaW terms. These terms include: i) all variants of “sustain” e.g. sustainable, sustainability, sustained etc. to represent sustainability part in our data; ii) variants of “happ” e.g. happy, happiness, happily etc. as a representation of wellbeing outcome; iii) “wellbeing” OR “wellbeing” and “welfare”. An important worth noting fact is during certain periods words “sustainability” or “sustainable” were avoided in New Zealand policy documents due to its very vague definition and conflicting understanding. However, there is a common understanding that it was replaced with term “resilience” during those periods. Therefore, we have also included the term “resilience” in our corpus for analysis. We build text corpus by searching any text containing the following substrings: “sustain” OR “resilience” OR “resilien” OR “wellbeing” OR “welfare OR “happi" OR “happy”. Some unwanted terms remaining in the cleaned text corpus (e.g. “chappie”) were also dropped.

5.3.2 Trends of SaW terms by political party

Our quest for knowledge began by analysing the trends of commonly used SaW terms in the text corpus using a slightly modified method adopted by Google Ngram. Google Books Ngram, plots the frequencies of text strings using a yearly count of n-grams found in sources printed over the period of more than 500 years between 1500 and 2008 in Google’s text corpora (Banerjee & Pedersen, 2003, Goldstone & Underwood, 2014, Gulordava & Baroni, 2011, Lin et al., 2012, Qasim, 2017). In our analysis we applied Equation 1 to calculate the normalised frequency of a term in a given year in order to extract annual trends of SaW terms:

[50] In text analysis it is a common practice to use word stemming technique to automatically accommodate all variants of a word. e.g. stem word for ‘running’ or ‘runs’ is ‘run’. For example see Lucas et al. (2015).

$$NTF_{i,y} = \log(\frac{W_i}{TWC_y}) \qquad (1)$$

where NTF_y represents the normalised frequency count of term i in year y; W_i is a selected SaW term and TWC_y is the total word count in year y. For instance, let's suppose term "sustainability" appears 44 times in the total word count of 181755 in the NZOYB of 2008, then the normalised frequency count of term "sustainability" is 2.42e-04.

5.3.3 Bigram analysis networks

Bigram analysis is one of the commonly used, yet very powerful techniques, to use to conduct the relationship between words in a text corpus (Banerjee & Pedersen, 2003, Feldman, Sanger, & others, 2007, Hall, Jurafsky, & Manning, 2008). We used the *"tidytext"* library in R programming language to extract tokenized text by pairs of adjacent words. For example, from phrase *"the definition of sustainable development is"* following bigrams can be extracted:

1. the definition
2. definition of
3. of sustainable
4. sustainable development
5. development is

It is important to note that commonly used words in English such as "the" or "of" are dispensable and thus are excluded in text analysis. The R library *"tidytext"* provides functionality to drop bigrams with a leading or trailing stopwords. It uses a built-in list of stopwords to identify them in the text corpus. In the above example, stopwords are underlined; and any bigrams containing a stopwords is eliminated from the text dataset (i.e. bigrams 1,2,3 and 5).

Results from the bigram analysis can be visualised using a Markov Chain model (Fabbrizzi et al., 2016, Feldman, Sanger, & others, 2007, Lucas et al., 2015). In this model, an un-directional network graph consisted of nodes (terms) and edges (the relationship between terms) is constructed from three variables of bigram analysis:

- from: the source node an edge is coming from.

- to: the end node an edge is going towards
- weight: a numeric value associated with each edge (i.e. count of bigrams in either direction).

Finally, the resulting networks are plotted using two other R packages; *"ggraph"* and *"igraph"*.

5.4 Results and discussion

Use of the words "sustainability", "wellbeing", and other selected SaW terms included in the corpus of NZOYBs, parliamentary debates and ministerial documents in our dataset, has changed significantly over time as shown in Figures 1 – 3. Similarly, the context in which these terms are used has also varied in different periods, as highlighted in bigram networks of correlated SaW terms in Figures 4 – 8. In this section, we will discuss key results in detail.

5.4.1 Trends of SaW terms

As shown in Figures 1 – 3, the terms "(un)happy", "sustain", "welfare" and "wellbeing" start to appear in the corpus from the first year of data (i.e. 1893) in NZOYBs and Hansard. The terms, "happy and "unhappy" have been used with fairly standard semantics, however with opposite trends. There is a decline in the use of the word "happy" during the Liberal party regime until 1935, when the Labour government was first elected, after that, the trend is reversed. In contrast, the term "unhappy" follows the exact opposite patterns in both periods (i.e. before and after the Liberal government).

The term "sustain" was used increasingly during the Liberal regime in both the NZOYBs and Hansard where the context was of maintaining certain levels of something e.g. "sustained yield" or "sustained injuries". The trend in the word count for the term "sustain" continue to grow, however, at much slower rate since late 1930s. The term "welfare" also exhibits a non-linear trend. Use of the word "welfare" continues to grow from the first year in our data i.e. 1893 and reached its peak by the mid-1980s after which the trends started to decline. This is the period when sustainable development was gaining the attention of policy makers globally, for details see (Qasim, 2017, 2018). During the late 1980s, after the Brundtland Commission's report "Our Common Future", sustainable development becomes a global agenda and the term "sustainability" and its variants are commonly used in policy debates and documents (Qasim, 2017). New Zealand also followed the same pattern which is reflected by the sharply increasing trends for words like "sustainability", "sustainable" and "sustainably" in our results shown in Figure 1 – 2.

Figure 1: Log normalized count of SAW terms in NZYBs by political parties

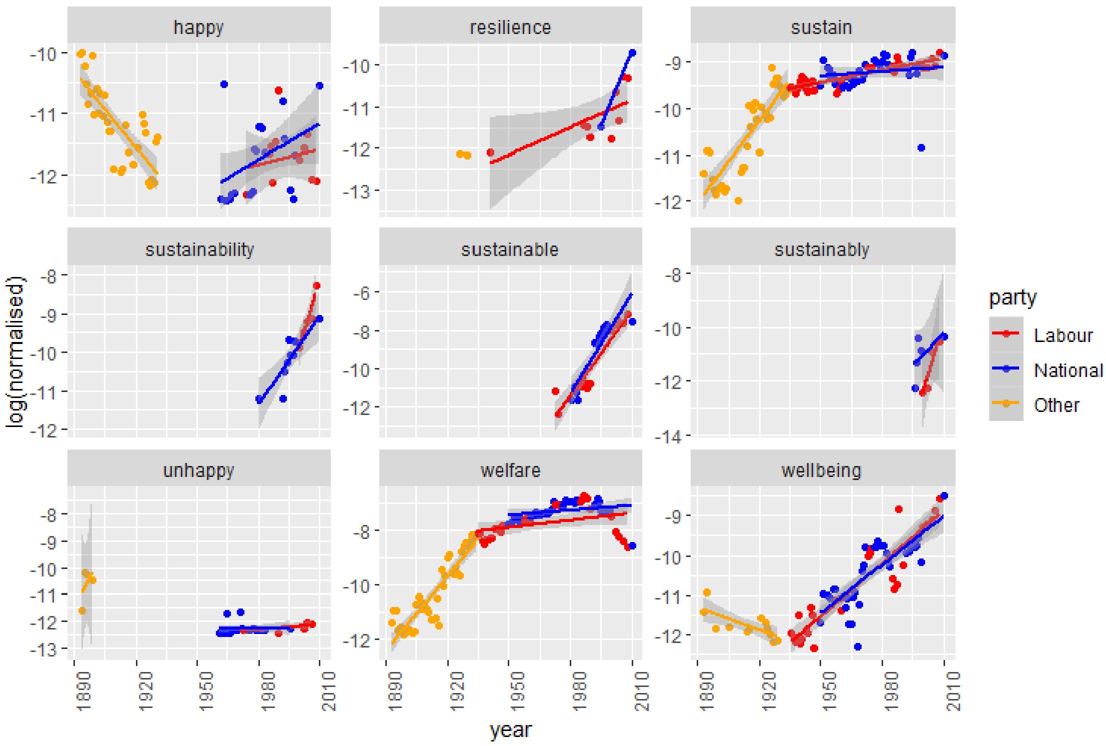


Figure 2: Log normalized count of SAW terms in parliamentary debates by political party

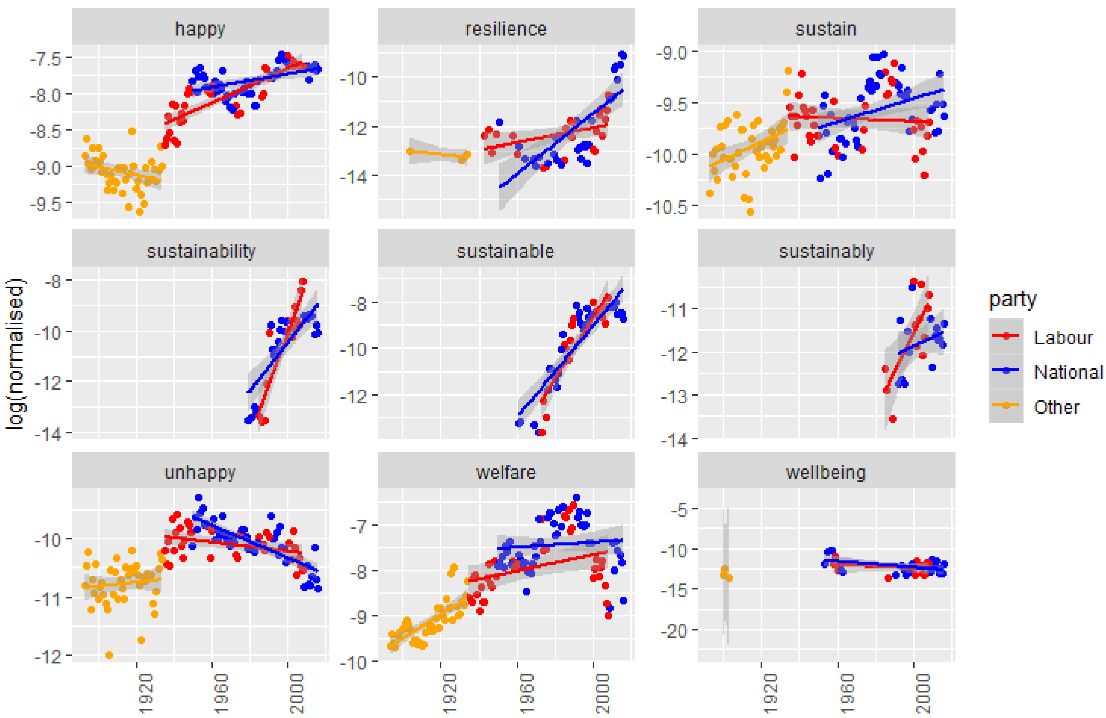
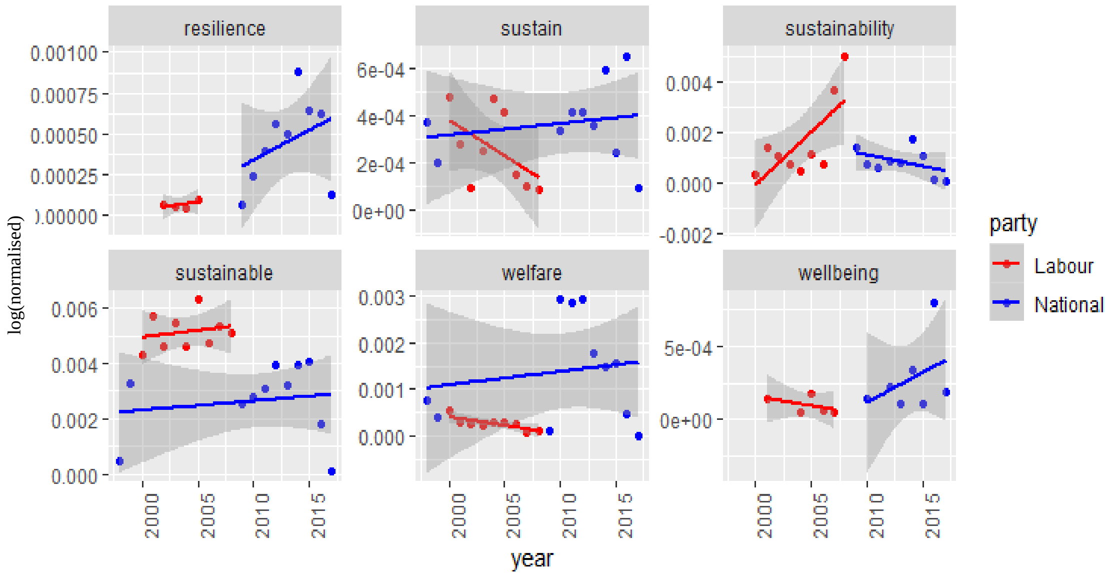


Figure 3: Log normalized count of SAW terms in ministerial documents by political party



The term “resilience” appeared in 1904 in parliamentary debates and in 1926 in the NZOYBs and has been used in a wide range of social and economic contexts with an overall increasing trend. For instance, in the sentences “Sarah Dowie: How does our economic resilience compare internationally?”[51], “I have immense faith in the resilience of human nature.”[52], “I am confident that it has resilience and the opportunity to take on any problem like this.”[53] etc.

The term “resilience” is particularly important among the selected SaW terms because it seems to have been used as a replacement for the term “sustainability” in recent years especially during the last National government period between 2008 and 2017. As identified in Figure 3, the term “sustainability” exhibited an increasing trend during the Labour government period between 1999 and 2008. The number of uses then plummeted when the National government came into power and the trend continued to decline during the following years of their tenure. The term “resilience”, however, was picked up as a replacement word in Ministerial documents as shown in Figure 3. This finding is consistent with the common understanding that the term “sustainability” became less popular during the National government tenure because they felt it was poorly understood, ill-

[51] Parliamentary debates on Tuesday, 28 June 2016 (for inclusion in Volume 715).
[52] Parliamentary debates., v.277 1947.
[53] Parliamentary debates., v.430, 12th June to 8th July 1980.

defined and had a vague agenda to follow. Helen Clark's government was criticised by National's for overusing the word "sustainability" in their conversations (Herald, 2009). This is also highlighted by the steeper slope for "sustainability" in Figures 1 – 2 under a Labour government.

Moving forward, the current Labour government is committed to maximizing environmental sustainability, coupled with higher levels of wellbeing through social housing, poverty reduction, extensive tree plantings etc. One of their significant steps in this regard is the adoption of The Treasury's "Living Standard Framework" (LSF) for setting priorities, decision making, and monitoring progress related to intergenerational wellbeing. It is, therefore, plausible to expect sustainability and wellbeing would have much stronger connections in any discourse analysis for Labour government in future.

5.4.2 Network analysis of SaW terms before and after 1970s

Figures 4 – 5 show the context in which SaW terms have been used before and after the 1970s using highly correlated bigram networks. During this time the notion of sustainable development had started to appear in United Nations' documents and was being discussed by policy makers worldwide (Qasim, 2018). In these networks of bigrams, each word is represented by a node and their link is illustrated by the edges linking two nodes. The thickness of the edge represents the degree of correlation between two terms i.e. thicker edge represents strong correlation.

Three standalone networks in Figure 4 (2), show the bigram relationship over the period 1893 – 1970 in NZOYBs. They reveal that SaW terms were used semantically during this time. Where the term "sustain(ed)" was used in a sense of maintaining the levels of something. for example, terms "sustain" is highly correlated with words like "capital", "rights", "force", "trade" etc. Likewise, the term "sustained" is also associated with words such as "forest", "management", "timber", "yield" etc. In addition, this is also linked with the term "welfare" which is linked with words like "people", "children", "environment", "child" etc. Figure 5 (2), illustrates the network diagrams from parliamentary debates over the same period and shows similar trends. The only difference, however, is that "welfare" and "happy" are not highly linked with terms like "sustain(ed)". In other words, SaW relationships did not exist in the published source literature before the 1970s, which is consistent with the finding of Qasim (2017, 2018).

In contrast, after 1970, we see a strong relationship between SaW terms in the context of sustainable development. As shown in Figure 4 (1), there is high correlation between the terms “welfare” and “sustainable” and “sustainability”. The terms “sustainable” or “sustainability” are strongly linked with words like “rio”, “climate”, “environment”, etc. and “welfare” is linked with words like “social”, “aged”, “persons” etc. Figure 5 (1) shows a similar pattern for parliamentary debates. However, the term “welfare” dominates the network in the centre and terms “sustain(ed)” and “sustainability” are linked back to it through some other words. This pattern explains the fact that “welfare” is more frequently used in parliamentary debates than in NZOYBs which is mainly a comprehensive snapshot of the New Zealand economy for a certain year.

Figure 4 (1): Correlation network of frequently occurring SaW terms in NZOYBs

After 1970

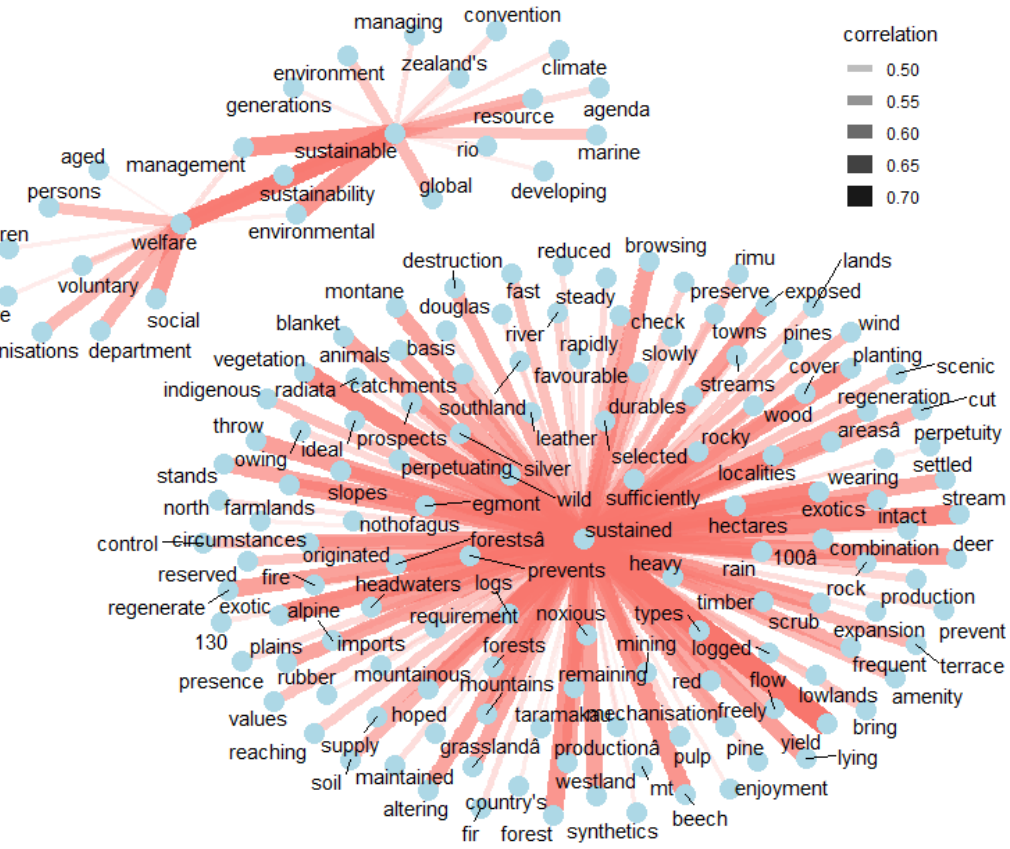


Figure 4 (2): Correlation network of frequently occurring SaW terms in NZOYBs

1893 – 1970

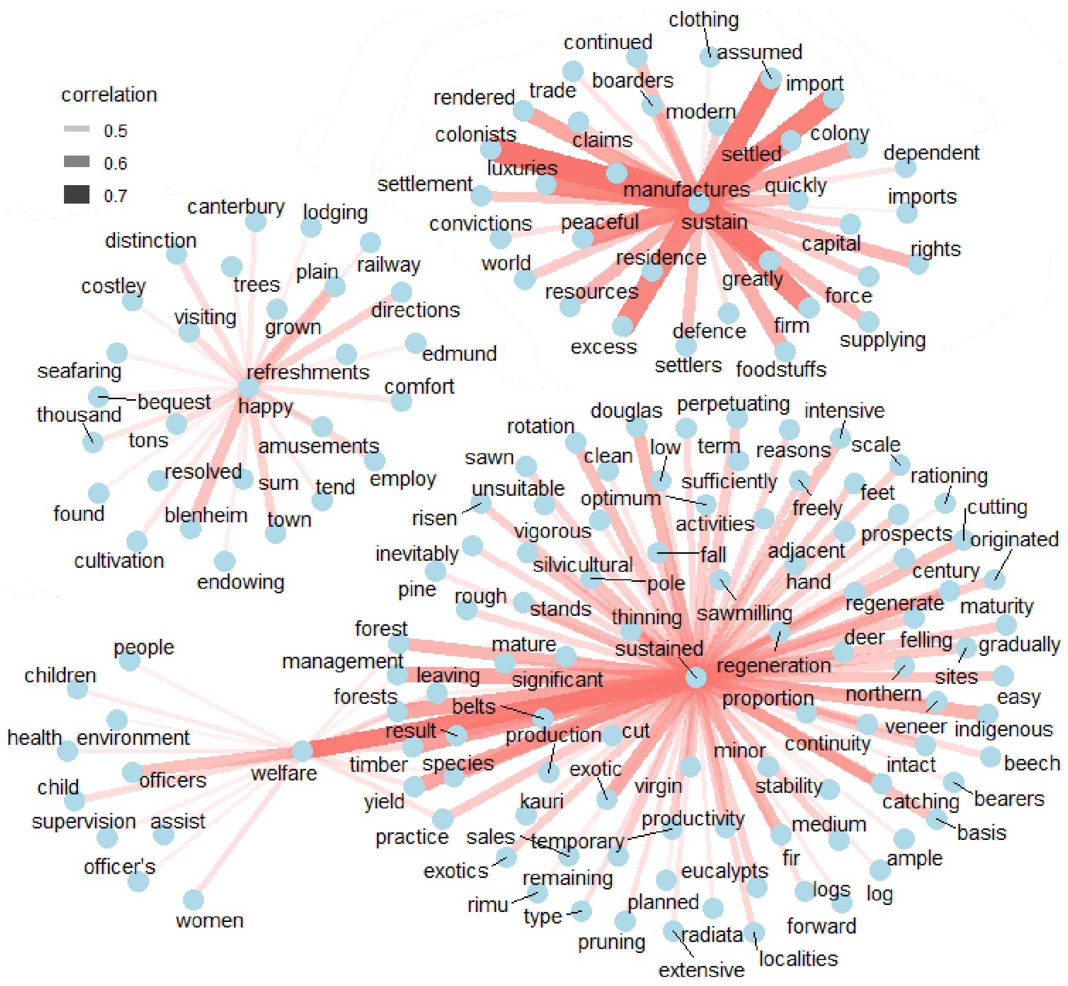


Figure 5 (1): Correlation network of frequently occurring SaW terms in parliamentary debates

After 1970

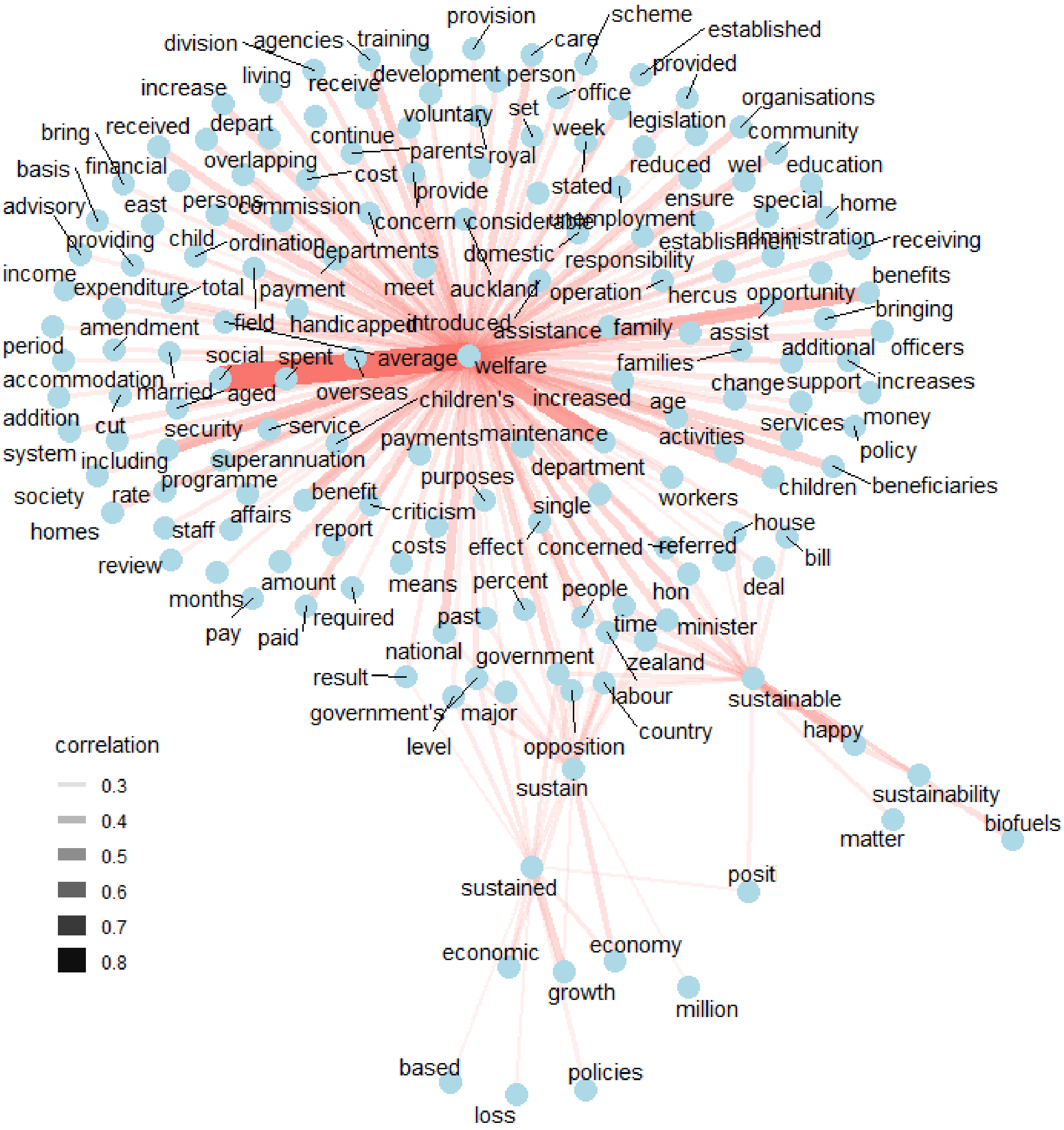
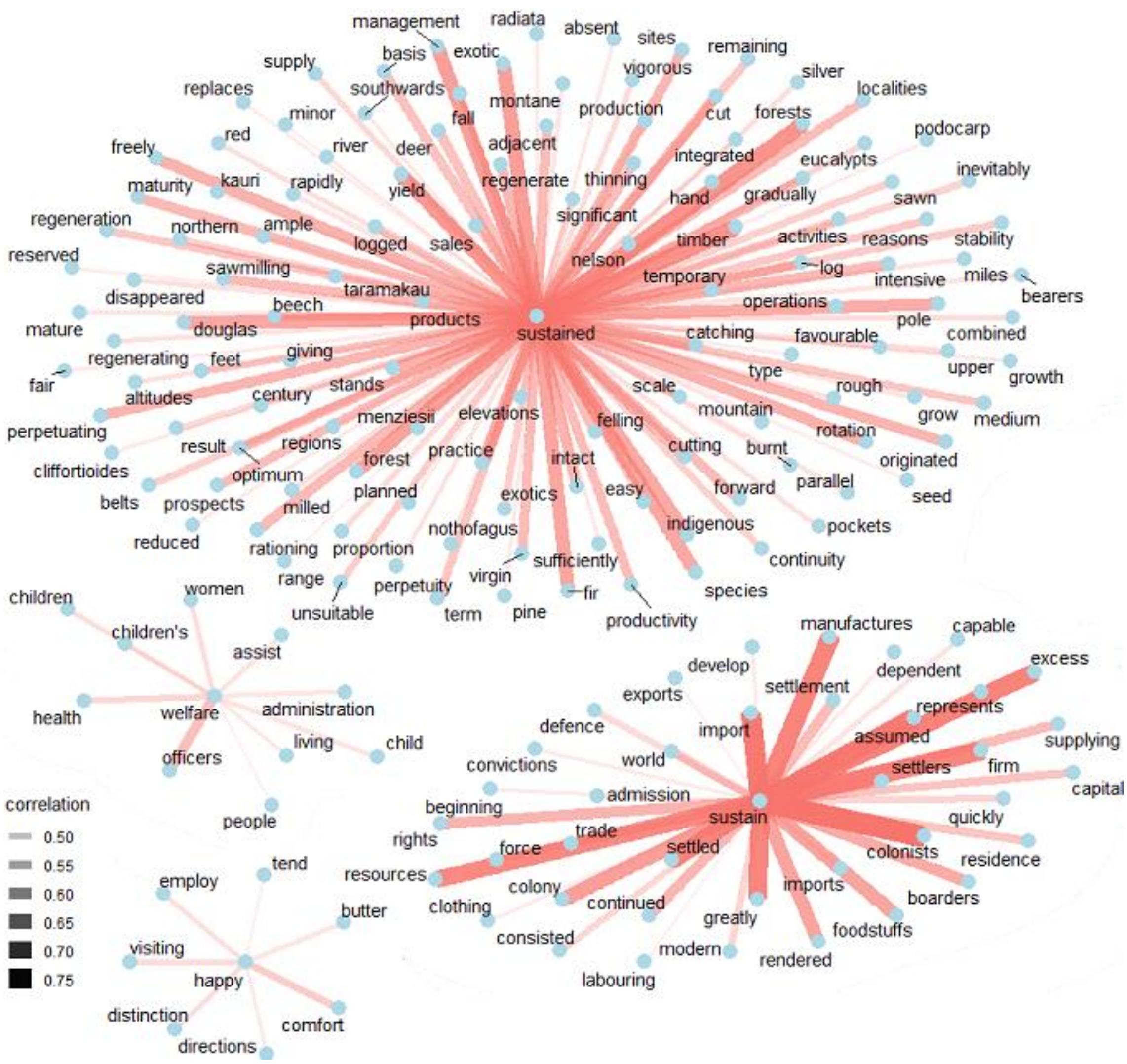


Figure 5 (2): Correlation network of frequently occurring SaW terms in parliamentary debates

1893 – 1970



5.4.3 Network analysis of SaW terms by political party

If we turn our focus to analyse the network diagrams of highly correlated SaW terms by political party in three text corpuses; NZOYBs, Hansard, and Ministerial documents. In this analysis, we took subsets of NZYOBs and Hansard text corpuses starting from year 1935 when Labour was elected for the first time. Furthermore, text data for the Labour party includes the years when Labour was in power and is the same for the National party text data.

At first glance, we see a stronger and denser relationship between SaW terms in all three networks shown in Figures 6 – 8 for the Labour party; and these terms align with the notion of sustainable development. For example, in the Figure 6 (1) network using the NZOYBs corpus, the terms “sustainable” and “sustainability” are linked with the words “development”, “environment”, “climate”, “rio”, etc. and the term “welfare” is linked with “care”, “social”, “accommodation”, “workers”, etc. In contrast, we observe a weaker relationship between “sustainable” and “welfare” for the National government in Figure 6 (2). It is also worth noting that the term “sustainable” is linked with the words “managing”, “marine”, “resources”, “fisheries” etc. for the National party. One might suggest that this relationship highlights the dominant focus of National’s supply side preference to deliver welfare. Furthermore, differences between highly connected words with SaW underpins the conflicting standpoints of political parties to articulate conceptually the same sustainability and wellbeing issues.

In the network diagrams for the NZOYBs, Figure 6 (2), we observe a direct link between “sustainable” or “sustainability” and “welfare” for both Labour and National party governments. There are two networks for each party; one linking “sustain”, “sustained” with other frequently co-occurring words; and the second linking “sustainable”, “sustainability” and “welfare”. One noticeable difference here is that the second network is denser and larger for Labour. Similarly, Figure 7 shows a network of words linked with SaW terms and other co-occurring words in the corpus of Hansard data which differ markedly for both political parties. The key difference is, all SaW terms with other co-occurring words are linked in one single network for Labour. This suggests that sustainability and wellbeing have been viewed as a whole during Labour’s various tenures. This is also reflected in the current Labour government’s adoption of LSF as mentioned earlier. Whereas, standalone networks for “sustainability” in Figure 7 (2) suggest that during National governments, “sustainability” and “welfare” are considered as two independent issues and thus were discussed separately.

Figure 6 (1): Correlation of frequently occurring SaW terms in NZOYBs by political party

Labour Party

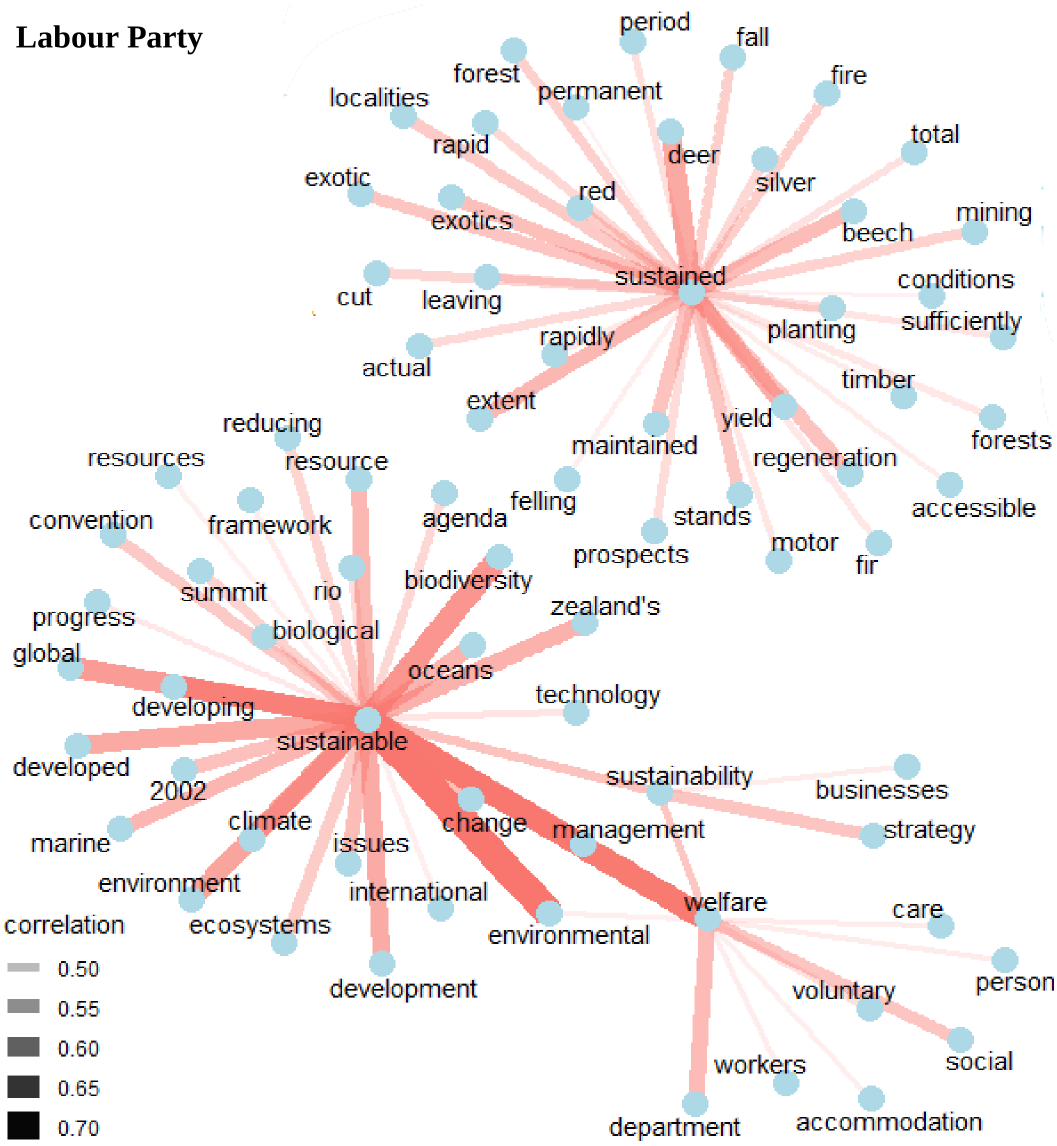


Figure 6 (2): Correlation of frequently occurring SaW terms in NZOYBs by political party

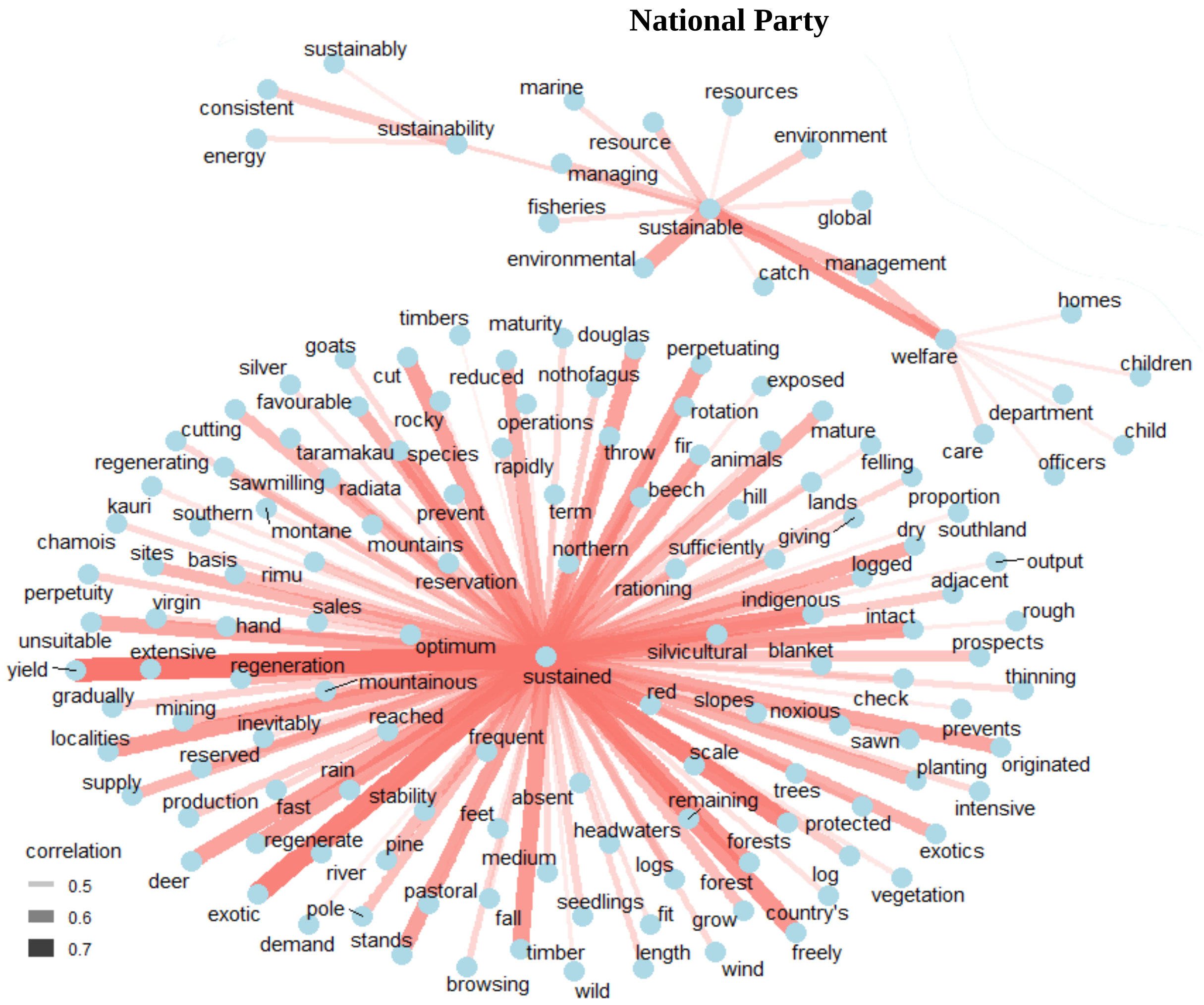


Figure 7 (1): Correlation of frequently occurring SaW terms in parliamentary debates by political party

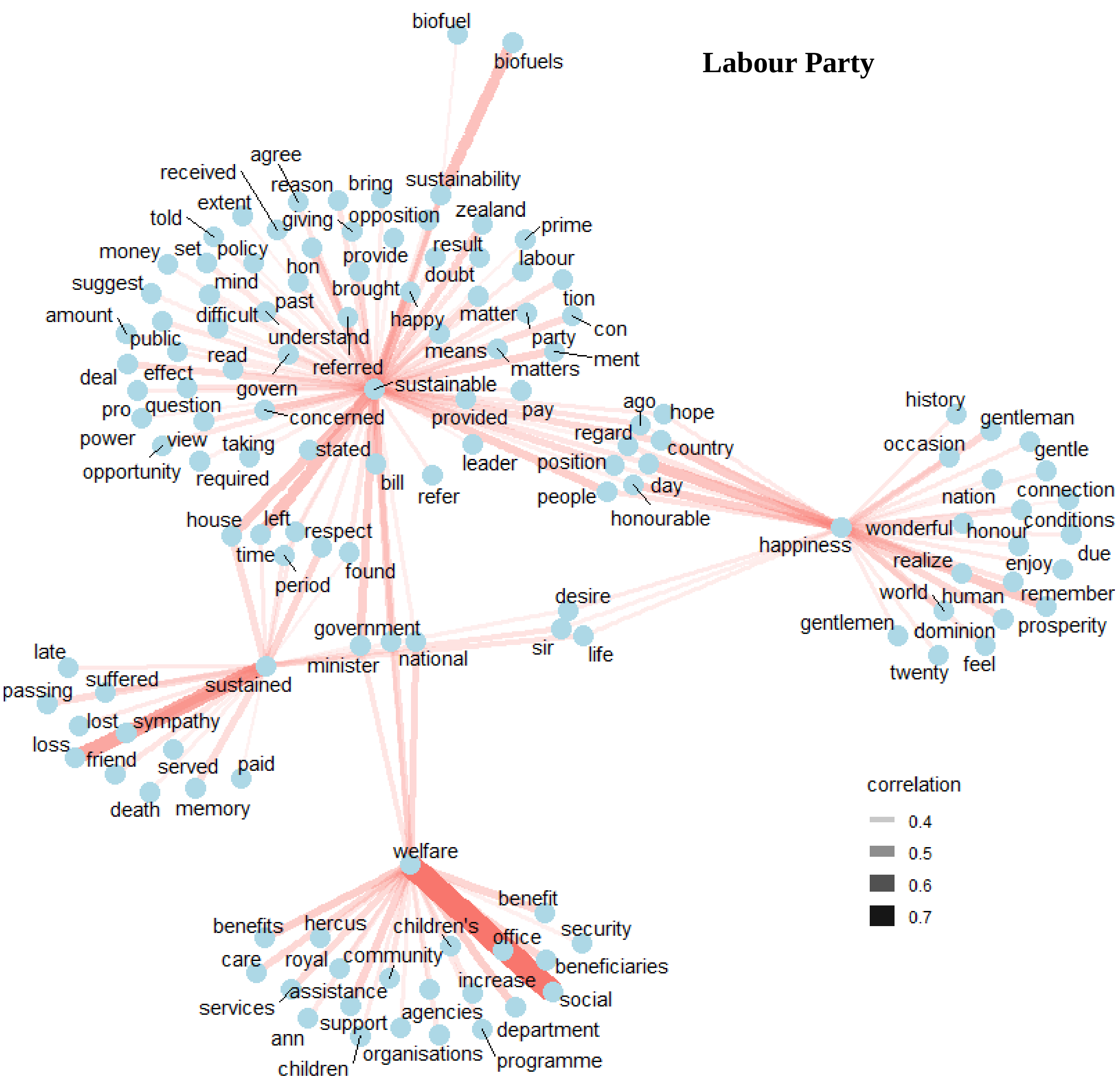
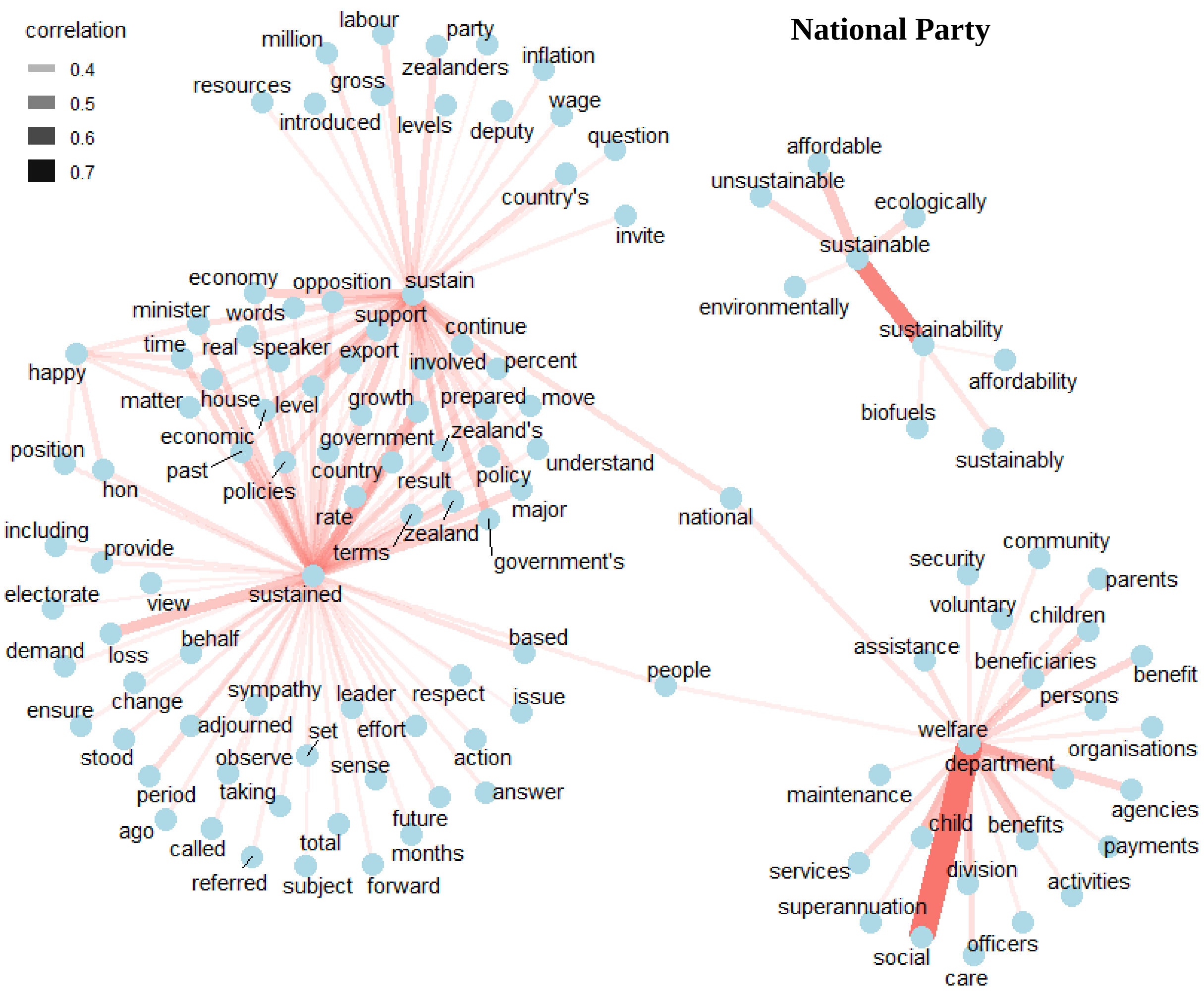


Figure 7 (2): Correlation of frequently occurring SaW terms in parliamentary debates by political party



Finally, Ministerial document networks presented as Figure 8, show that SaW are presented together under both Labour and National governments.

Figure 8 (1): Correlation of frequently occurring SaW terms in Ministerial documents by political party

Labour Party

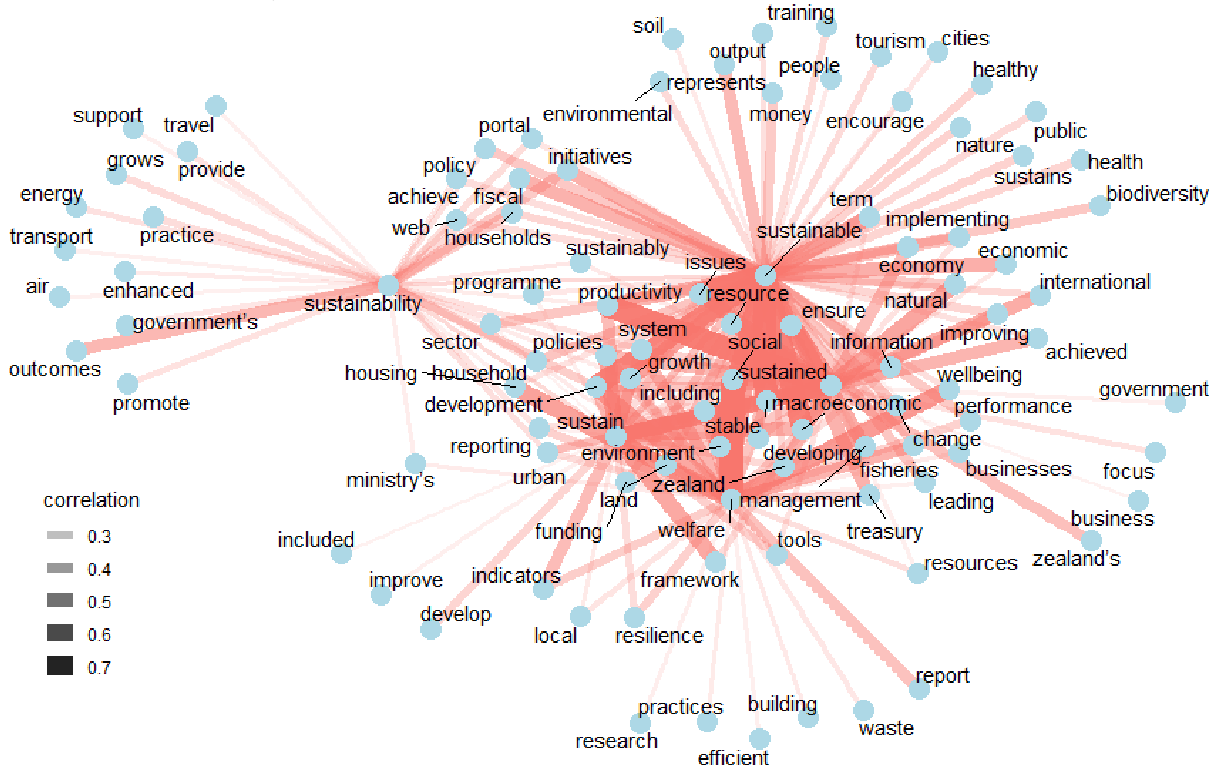
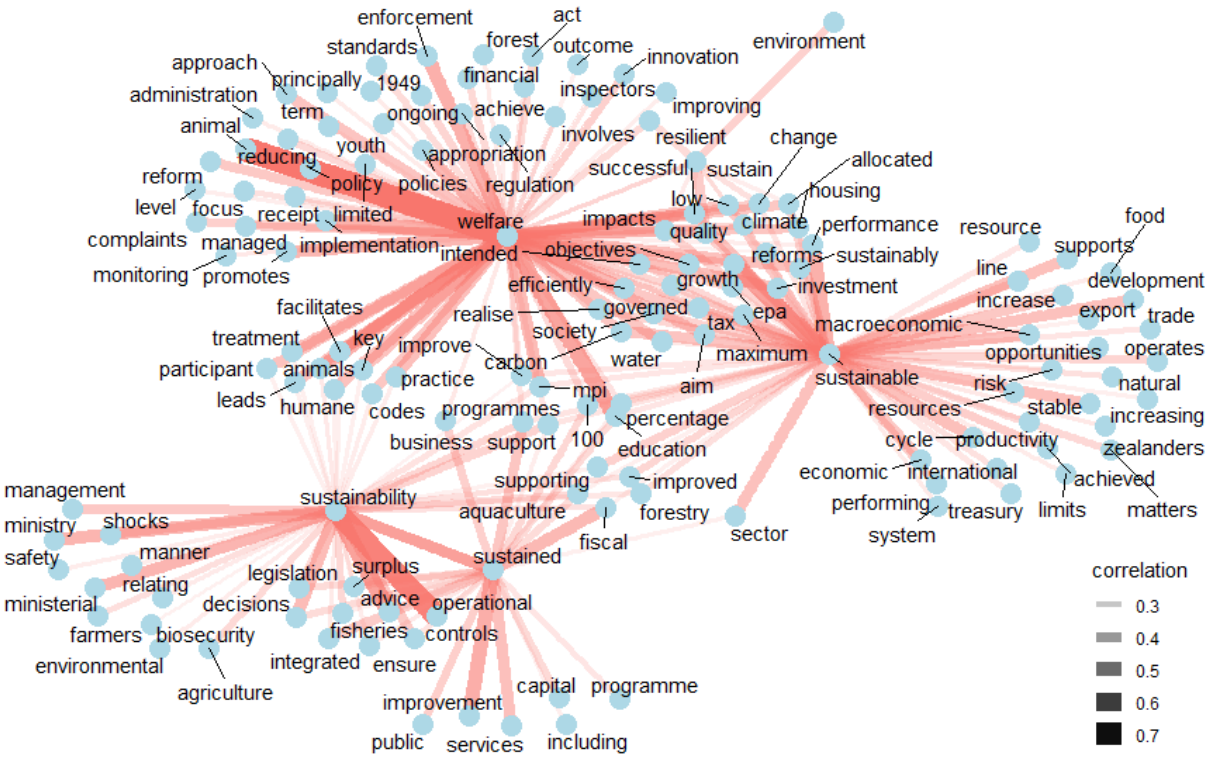


Figure 8 (2): Correlation of frequently occurring SaW terms in Ministerial documents by political party

National Party



5.5 Conclusions

Sustainability and wellbeing are inter-related subjects often discussed in conjunction with each other in the literature (Qasim, 2017, 2018). However, there has been very little investigation into how politicians articulate these issues and how these issues are reported in policy documents. This paper is an effort to fill this gap by conducting advanced corpus analysis including key SaW terms' analysis, to identify their historic trends and to analyse their evolution using bigram network analysis to underpin how SaW terms are associated with each other. The global sustainable development movement following the Brundtland Commission's Report affected SaW references in New Zealand.

Methodologically, this paper is one of the early studies in social science to make use of powerful text analysis methods to analysis enormous text data. Empirical analysis on text data using traditional methods mostly relies on data that are not observed directly, rather are quantified by historians or experts who analyse and interpret qualitative resources. Although this is generally accepted as a valid way of data transformation, such processes are driven by the expert-opinions and are inherently unrobust as it is almost impossible to replicate or match with the ground truth (Benoit et al., 2016).

Our key results highlight that the term “welfare” has existed in the NZOYBs and Hansard data from 1893 (which is the first year in our dataset) with and increasing trend for almost a century. This mirrors the long history of social welfare-oriented policies in New Zealand. The terms “wellbeing” and “sustain” also stretch over the same period. The term “wellbeing” gained momentum in the mid-1930s when the Labour government was first elected, after which it was used frequently in a wide range of social, and economic contexts. The term “sustain” has also been used semantically to show maintained levels of something e.g. sustained yield.

Network analysis of correlated bigrams shows that “wellbeing”, “welfare”, “sustain” were typically used independently before the 1970s. After the 1970s, the term “sustainability” started to appear in the text corpus with a sharply rising trend. This is the time when sustainable development was entering the agenda of several governments around the world. Brundtland’s report catalysed this trend further. After that, the terms “sustainability” and “wellbeing” started to co-occur frequently as shown in our network analysis results. In terms of political parties, we see co-occurring words with SaW terms that differ significantly for the Labour party and the National party. Such differences highlight the apparent varying SaW perspectives of the ruling party. For example, the network density of a SaW network from the NZOYBS (Figure 6) is denser for the Labour party compared to that of the National party; and in the Hansard network (Figure 7) we observe a disconnect between “sustainability” and “welfare” networks for the National party whereas these are linked in the case of Labour. It shows that when National is in power, sustainability and wellbeing seem to be viewed as two separate issues and are typically not discussed together or one of the terms is simply neglected for any reason. In contrast, Labour appears to view SaW as a whole. This to some extent is also confirmed by their elevation of Treasury’s LSF for decision making.

Limitations of the study

This work could have been improved significantly by performing some statistical analysis of the network such as degree of centrality, Modularity, Eigenvector centrality etc., if time was not a constraint. These networks could also have improved by diving them into smaller time intervals to get even more fine-grained results should time and resources have allowed.

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Appendix

Timeline of major economic events

Year	Event
1891	Liberal government formed
1901	Australian states form a federal government—New Zealand opts not to join
1907	New Zealand constituted as a Dominion
1914–18	First world war
1918	Influenza epidemic
1922	Meat Producers" Board placed in control of meat exports
1929	US share market crash
1932	Ottawa agreement: Britain retreats from free trade
1935	Labour elected
1936	Reserve Bank nationalised
1938	Social Security Act; import licensing introduced
1939–45	Second world war
1946	Family benefit introduced; Bank of New Zealand nationalised
1947	Statute of Westminster adopted by Parliament
1948	Economic Stabilisation Act
1949	National government elected
1950	Legislative Council abolished
1951	Waterfront dispute
1965	New Zealand Australia Free Trade Agreement (NAFTA)
1967	Robert Muldoon becomes Minister of Finance
1973	Britain joins EEC; oil prices rise sharply following the Israeli-Arab war
1975	Waitangi Tribunal established
1979	Oil prices rise sharply following the revolution in Iran
1982	• Comprehensive, freeze imposed on wages, prices, interest rate, and rents. • Major tax cuts announced to support the program.
1983	• Closer Economic Relations (CER) Agreement with Australia signed with an aim to allow free trade with Australia. • Effective date for first stage of deregulation of land transport. • Industrial Law Reform Bill, enabling voluntary unionism, is passed.
1984	• Abolishment of Supplementary Minimum Price subsidy scheme for farming. • Labour elected in the general election with 56 seats, and Sir Roger Douglas becomes Minister of Finance. • Government announced program to remove all major export incentives and reduce import protection. • Remaining interest rate controls abolished. • Budget removes many subsidies and incentives. • Abolishment of exchange controls.
1985	• New Zealand dollar floated funds outflow which largely deprived the banking system of reserves. • Abolition of limits on foreign ownership in New Zealand financial institutions, advertising agencies, and fish processors. • Major review of quality of state spending. • Significant increase in minimum wage and family incentives. • Lower tariffs to assist exporting farmers.
1986	• Statement on Government Expenditure Reform. • Comprehensive goods and services tax introduced at a uniform rate of 10 percent, the top personal income tax rate to be reduced from 66 percent to 48 percent.
1987	• Share market crash • First (partial) privatization to assist the Bank of New Zealand to raise capital • Nine new state-owned enterprises formed.
1988	• Flat tax and family income measures suspended. • Reduction of the top personal income tax rate from 48 percent to 33. • Further budget cuts expenditure to reduce national deficit.
1989	• Corporate tax rate to rise from 28 percent to 33 percent.
1990	• National wins general election with 67 seats.

	• Complete free trade of goods with Australia under the 1983 CER agreement. • "Economic and Social Initiative" involving wide-ranging welfare benefit reforms.
1991	• Employment Contracts Act • Most benefits are cut. • Further budget cuts spending.
1992	• Health reforms take effect.
1993	• Budget continues to move toward reducing expenditure and net public debt as a percentage of GDP and to move toward fiscal surpluses. • Hung parliament with 50 seats of National, 45 of Labour, 2 of Alliance, and 2 of New Zealand First 2 in the 99-seat parliament.
1994	• Moody's Investor Services upgrades New Zealand government long-term overseas debt after a long time from AA3 to AA2. • Fiscal Responsibility Act passed. • Tariff reductions on key products.
1995	• First Budget Policy Statement under the Fiscal Responsibility Act.
1998	• Drought; Asian crisis.
2000	Employment Relations Act; free trade agreement with Singapore
2001	US-led global slowdown; Kiwi migrants to Australia need permanent entry status to qualify for welfare benefits
2002	New Zealand GDP growth per capita overtakes OECD average
2007	The threat of inflation pushes interest rates and the New Zealand dollar to a post float high against the US dollar
2008	NZ-China free trade agreement
2008-09	Global Financial Crisis; Canterbury earthquakes
2011	Rugby World Cup
2015	TPP agreed
2017	Labour wins general election 2017
2018	Government redefined social policies; wellbeing budget

Sources: NZOYBs; Olssen and Stenson (1987); Dalton and Watters (1999); Briggs (2003); Evans et al. (1996).

Chapter 6: 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

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6.1 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)[54]. 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

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

which income from the use of non-renewable resources should be reinvested in renewable resources in order to 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[55]). 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

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

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 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.

6.2 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:

$$g = \dot{k} - F_R r - \gamma\omega \qquad (2)^{56}$$

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.

[56] 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.

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

6.2.1 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 two different 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[57] 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).

6.2.2 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

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

Bank data. FV 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_2 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.

6.3 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

6.3.1 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

6.3.2 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).[58] 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

[58] See appendix for details on rent calculations.

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.

6.3.3 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 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 approximately 2.9% 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.

6.3.4 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).

6.3.5 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.

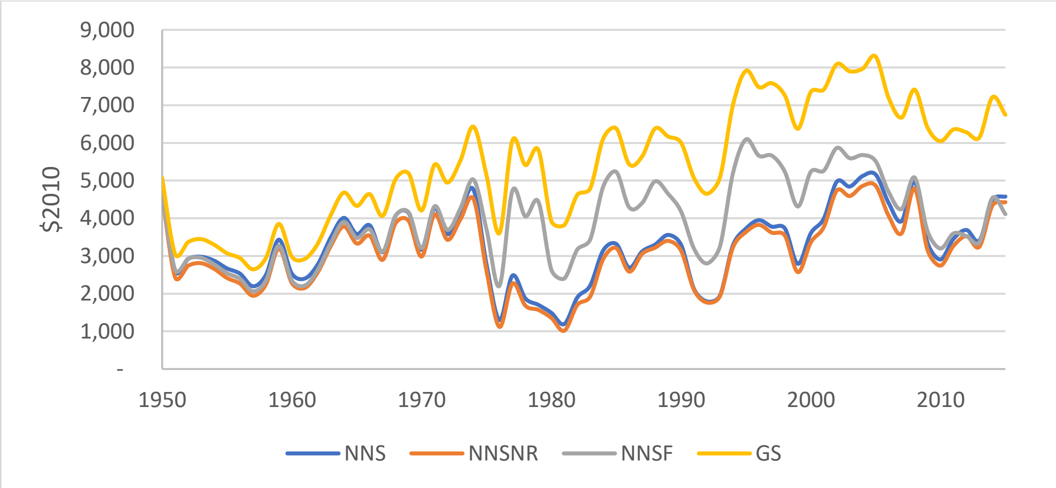
6.3.6 Consumption per capita and GDP per capita

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.[59]

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.

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



[59] 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 3: Alternative measures of future well-being as a percentage of GDP

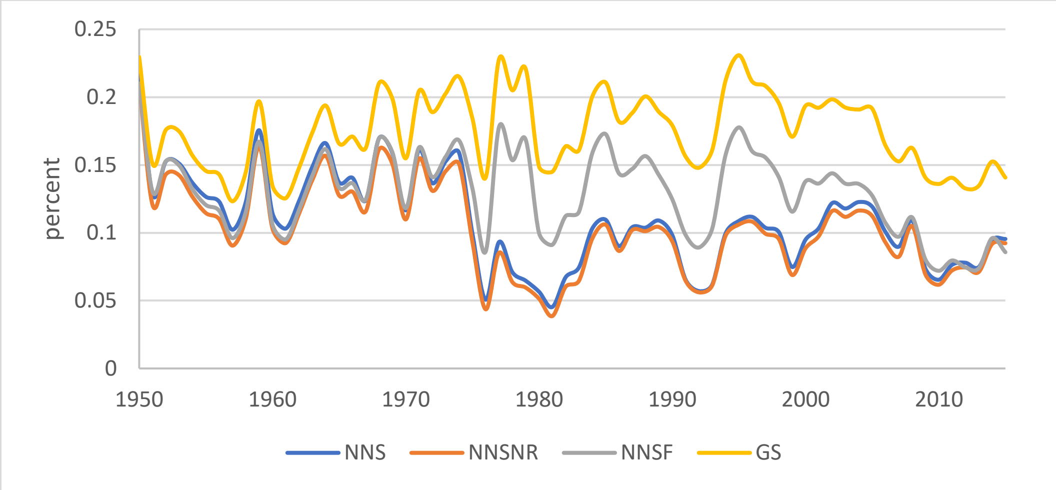


Figure 4: New Zealand forest volumes

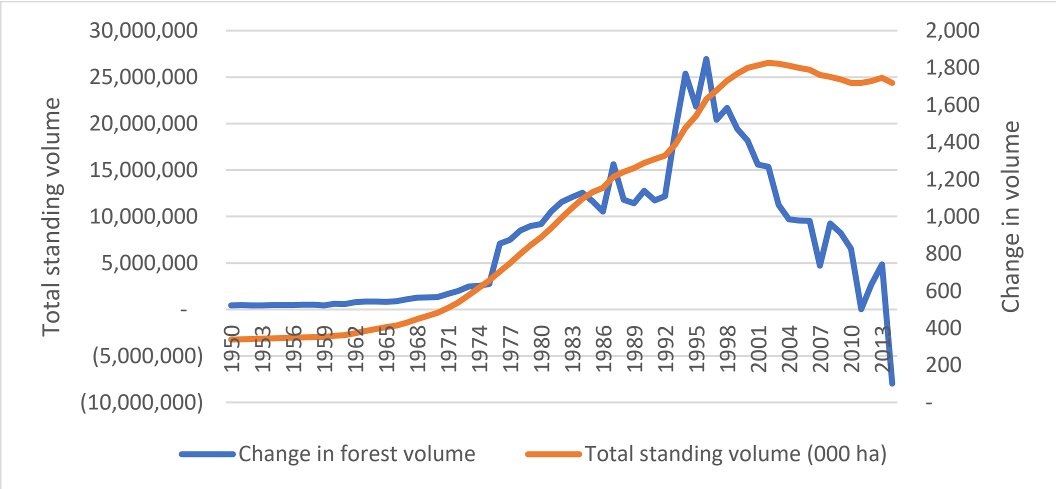


Figure 5a: PV of technological progress augmented NNSNR measure as a percentage of GDP at 2.8% discount rate over t=10, 15, 20, 30 year horizons

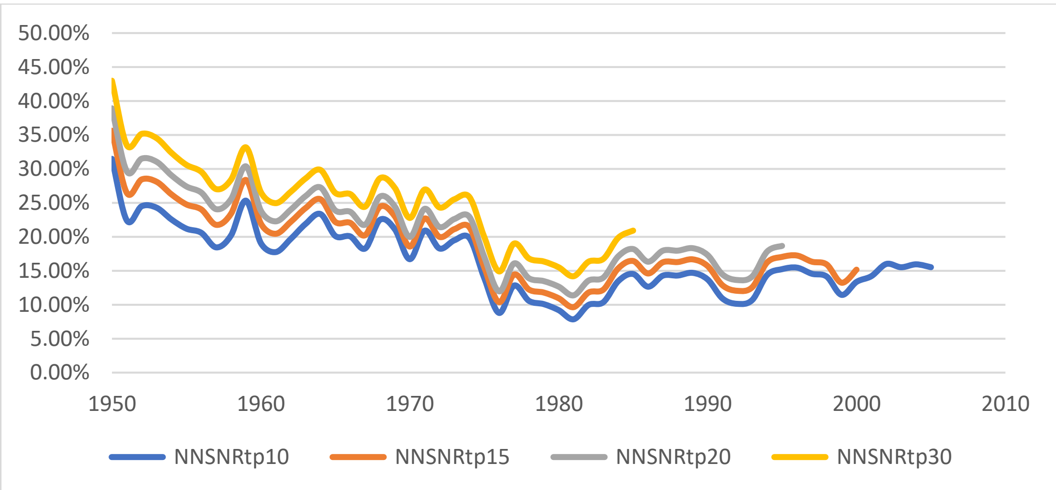


Figure 5b: PV of technological progress augmented NNSF measure as a percentage of GDP at 2.8% discount rate over t=10, 15, 20, 30 year horizons

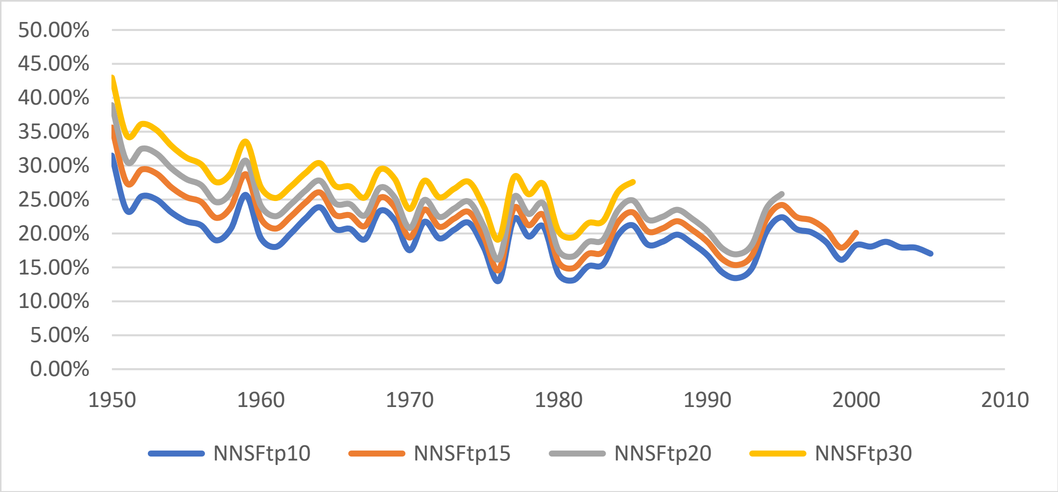


Figure 5c: PV of technological progress augmented GS measure as a percentage of GDP at 2.8% discount rate over t=10, 15, 20, 30 year horizons

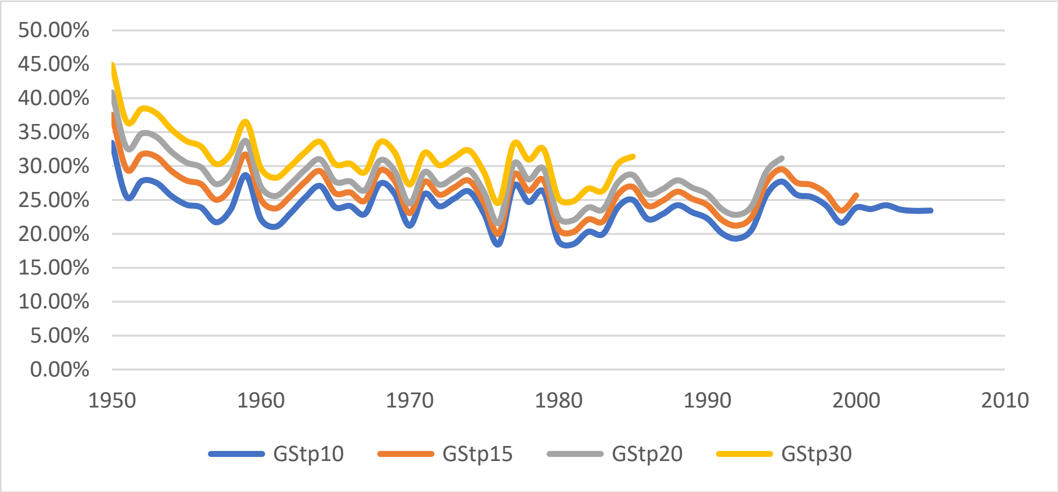


Figure 6: PV of future changes in real GDP over t=10, 15, 20, 30 year horizons with 2.8% discount rate

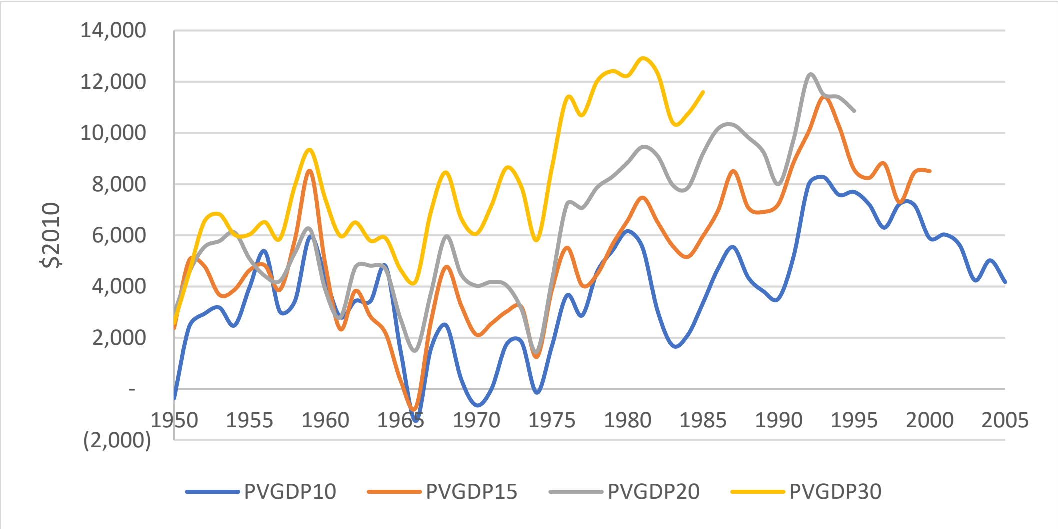
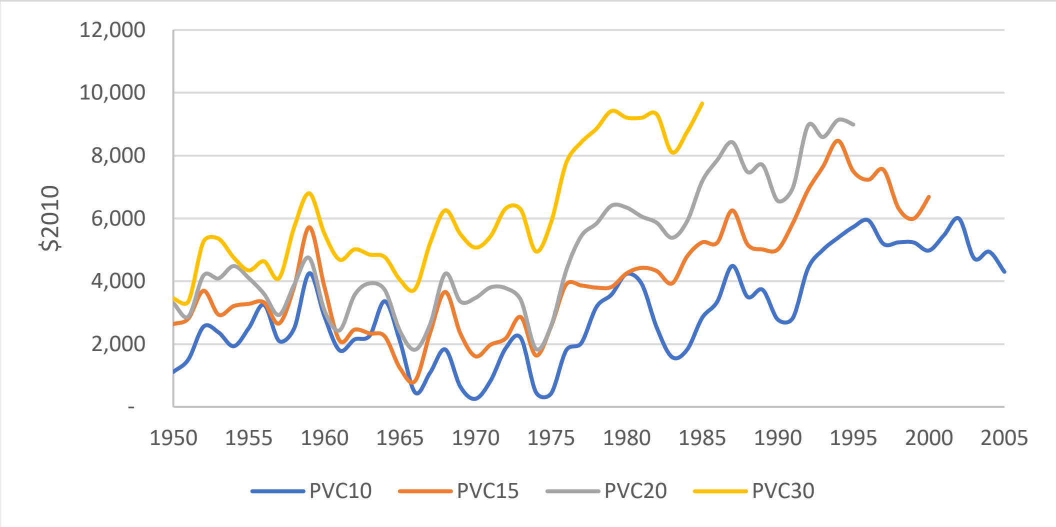


Figure 7: PV of future changes in real consumption over t=10, 15, 20, 30 year horizons with 2.8% discount rate



6.3.8 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.

6.3.9 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.

6.4 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.

6.4.1 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.

6.4.2 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.

6.4.3 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

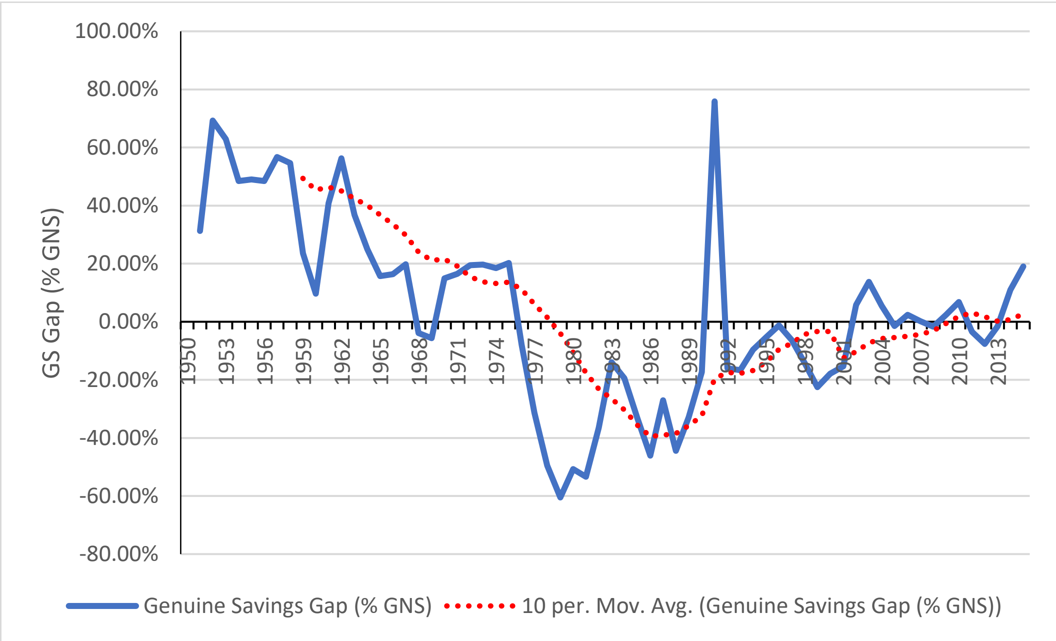
Period	Avg. GS Gap (% GNS)	Avg. GS Gap (% GNS) WB format
1955 - 2015	0.5%	0.5%
1970 - 2015	-9.0%	NA
1985 - 2015	-6.4%	NA
2000 - 2015	7.2%	7.2%
1955 - 1975	15.1%	15.1%
1975 - 1995	-22.7%	NA
1995 - 2015	-1.5%	NA
2004 - 2006	2.1%	2.1%

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%

6.4.4 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)

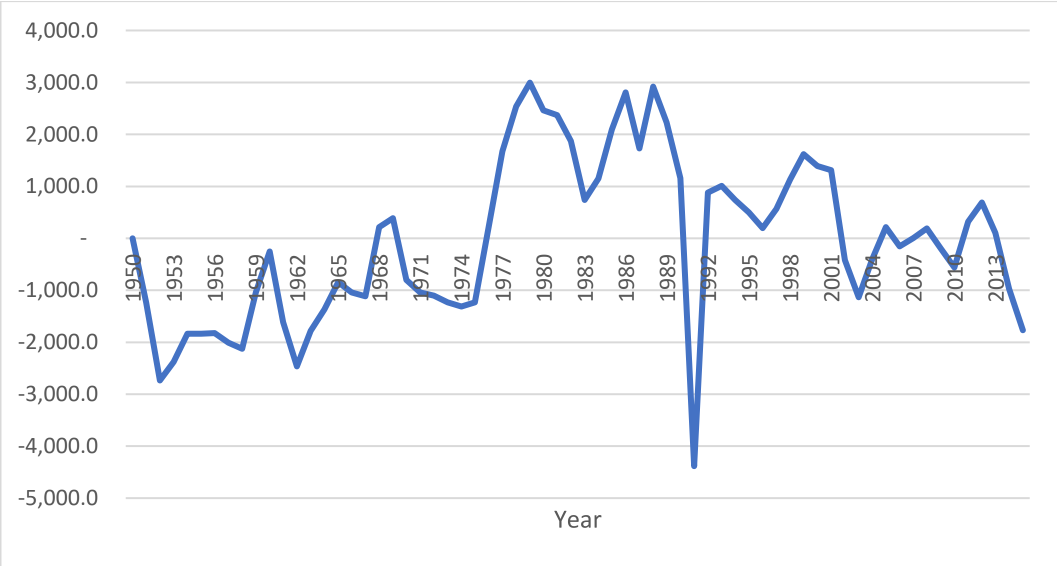
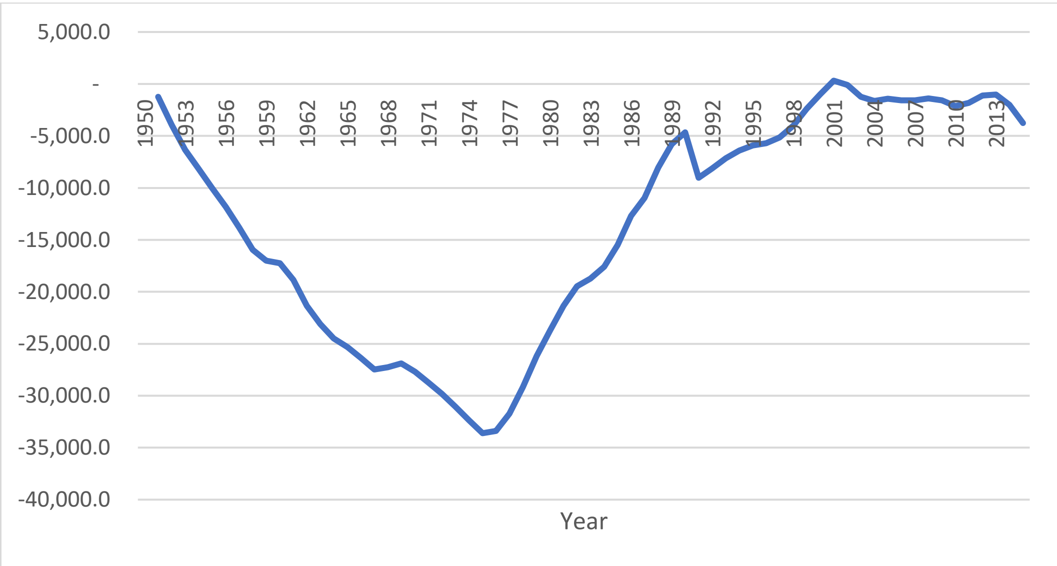


Figure 10: Cumulative change in wealth per capita



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.

6.4.5 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.**

6.5 Discussion

6.5.1 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[60] 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[61]. The average GS to GDP ratio as reported here has been around 17%, which is sufficient

[60] See Appendix for detailed results

[61] 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."

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 period. This suggests New Zealand has maintained higher levels of genuine savings[62] 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)[63].

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.

6.5.2 *Some potential government policy-related issues to consider*

6.5.2.1 Issues

[62] 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."

[63] "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.

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*
- 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[64].
- 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.

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

6.5.2.2 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:
    - 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[65] 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)

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[65] 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

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.

- 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'[66].
- 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.

6.5.3 Some caveats and potentially fruitful areas for ***further research***

This is only the second[67], 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

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[66] "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

[67] World Bank (2011)

important when calculating GS (without augmentation by TFP) where its contribution is relatively large in New Zealand.

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[68]. Further work in this area would be an important future development of this programme of research[69].
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'

[68] "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.

[69] "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.

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 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.

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 A1: 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	World Bank national accounts data files.	Gross national savings are calculated as Gross Fixed Capital	The New Zealand Official Yearbooks and Stat NZ InfoShare

	public and private consumption, plus net current transfers.		Formation + Change in inventory (Annual-March) in NZD	
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 A2: 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 A3: 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
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 A4: 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.

Chapter 7: Sustainable economic policy and well-being: The relationship between adjusted net savings and subjective well-being

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Abstract

We analyse the relationship between subjective wellbeing (SWB) and World Bank's indicator for long-term weak sustainability adjusted net savings (ANS). Our study focuses on adopting ANS to model SWB at individual level as well as aggregated group level. Our empirical models rely on World Values Surveys (WVS) data for self-reported life-satisfaction (our proxy for SWB) and other personal details combined with World Bank's data on ANS and other macroeconomic variables. Our results show that ANS is negatively associated with SWB in the short-run. This explains an important challenge of a political economy in which countries starting off with lower ANS tend to spend more on the well-being of their current generation at the expense of future generations' well-being. Such policies tend to increase well-being of people in the short-run but diminishes the reserves to raise or sustain well-being over the long-run. However, over the long-run, this relationship is reversed (but not significantly different from zero in our results). This change reinforces ANS being a sustainability indicator for infinite time horizons and our longest time period is only 20 years due to data limitations which is relatively shorter timespan with intertemporal models like ANS. Such analysis will become highly beneficial as more data from WVS becomes available in future.

JEL codes: D91, H75, Q01, Q56, R23

Keywords: Adjusted net savings, subjective wellbeing, intergenerational sustainability

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7.1 Introduction

We examine the relationship between the individual well-being of citizens and the degree of sustainability of economic policies at the national level. In doing so, we highlight a difficult trade-off that governments must make between running sustainable economic policies and raising the more immediate welfare of their citizens. This trade-off helps to explain why many governments fail to adopt sustainable economic policies even though by doing so they would improve the well-being of future generations.

The World Bank's adjusted net savings (ANS) series has been widely adopted as a comprehensive indicator to measure sustainability over the long-run (Arrow et al., 2012, Ferreira & Vincent, 2005, Greasley et al., 2014, 2016, Hanley, Dupuy, & McLaughlin, 2015)[70]. Starting with Ferreira, Hamilton, & Vincent (2008), many researchers have applied ANS as a predictor of aggregate objective well-being. However, far less attention has been given to testing the relationship between ANS and subjective well-being at individual level. The present paper aims to fill this gap by examining the relationship between ANS and life-satisfaction[71] which is a commonly used proxy of subjective well-being (SWB). To the best of our knowledge, this study is the first to test whether ANS helps to predict developments in life-satisfaction at individual level.

We explore the relationship between individual level SWB and ANS using both ordinary least squares (OLS) and ordered logit regression models. We also explore the relationship between aggregated group level SWB and ANS using pseudo-panel OLS models created by aggregating data into several groups defined by various age and sex combinations.

[70] ANS is also referred to as genuine savings (GS), comprehensive investment (CI), comprehensive savings (CS) or inclusive wealth (IW) in the literature. ANS has been developed in many ways in terms of time horizon, model specification and its components. For example, it has been expanded over very long time-horizons by Blum, McLaughlin, & Hanley (2013), Greasley et al. (2014) and Hanley et al. (2016) and they refer it as genuine savings (GS). Qasim, Oxley, & McLaughlin (2018) expanded ANS by incorporating forestry and expanding time-horizon for New Zealand and also call it GS. Greasley et al. (2016) has expanded ANS model by adjusting it for minerals and TFP for Australia and they call it comprehensive investment (CI). Similarly, it has been referred to as comprehensive wealth in (Ferreira, Hamilton, & Vincent, 2008). In this paper, all these terms are used interchangeably for World Bank's ANS.

[71] The terms life-satisfaction and SWB have been used synonymously in well-being literature and we will also use these terms interchangeably in this paper.

We find that initial levels of ANS for a country are *negatively* associated with the future SWB of its inhabitants over relatively short time horizons e.g. up to 15 years; and the link is highly significant. This relationship, however, turns *positive* and, for the cross-sectional OLS estimates, significant as the time horizon becomes longer. A negative relationship between ANS and SWB in the shorter periods is consistent with countries that have high (low) initial levels of national savings tending to spend less (more) on the welfare of the current generation. Over longer time periods, the investment in future generations exhibited by countries with high levels of ANS can be expected to raise future levels of SWB as resources are set aside for future generations. This is consistent with the positive relationship between ANS and future SWB over our longest timespan. One reason that the relationship between ANS and SWB is positive only for the longest timespan in our results is likely to be due to the fact that ANS is conceptually a tool to measure sustainability over infinite time horizons (Blum, McLaughlin, & Hanley, 2013, Greasley et al., 2014). Our results are consistent with this relationship becoming significantly positive over longer durations but at the expense of immediate SWB outcomes.

To minimize the risk of omitted variable bias, we control for personal variables which have been shown to be linked with SWB such as age, sex, income, marital status, employment status and education (collected in World Values Surveys face-to-face interviews) as well as macroeconomic variables such as real gross national income (GNI) per capita, unemployment rate and inflation rate as suggested by a number of SWB studies (Bonini, 2008, Engelbrecht, 2009, Gnègnè, 2009, Grimes et al., 2016, R. Tella, MacCulloch, & Oswald, 2001).

The remainder of this paper is organized as follows: section 2 describes ANS and SWB in detail and reviews the relevant theory. Section 3 explains the specifications of the empirical models with a detailed description of variables. Section 4 covers the process of collecting data from several sources and explains how data is processed. In section 5, we present the results from the empirical models with a detailed discussion of research findings. In the final section, conclusions are drawn with a re-enforcement of key findings.

7.2 Background

7.2.1 What is Adjusted Net Savings?

ANS is an indicator to measure sustainable development at the macro-level over the long-run (Arrow et al., 2012, Blum, Ducoing, & McLaughin, 2017, Gnègnè, 2009, Greasley et al., 2014, Hamilton & Clemens, 1999, Pezzey, 2004). ANS was first introduced by Pearce & Atkinson (1993) as an indicator of "weak sustainability"[72] based on the reformation of the Hartwick Rule (Hartwick, 1977, 1990). According to the Hartwick Rule income from the exploitation of non-renewable resources should be reinvested in renewable resources in order to maintain total wealth and to achieve non-declining well-being over time. This rule emerged from the Hicksian definition of income as being the maximum amount of consumption in one period that does not compromise the ability to afford the same level of consumption in the following period (Hicks, 1946).

Pearce and Atkinson (D. W. Pearce & Atkinson, 1993, W. D. Pearce, Markandya, & Barbier, 1989) defined a sustainable economy as one which saves more than the combined depreciation of its stocks of natural capital and produced capital. Whenever ANS takes negative values, it indicates an unsustainable development path. Similarly, according to (Hamilton & Atkinson, 2006), if the total wealth (i.e. sum of all types of capital stocks i.e. human capital, produced capital and natural capital) is related to social welfare, then sustainability necessarily involves maintaining total wealth. In other words, a non-declining level of per capita total wealth has to be maintained intergenerationally to realise sustainability (Dasgupta & Mäler, 2001).

ANS is calculated by the World Bank as net national savings plus education expenditure, and minus energy depletion, mineral depletion, net forest depletion, and carbon dioxide and particulate matter (PM) emissions damage. The World Bank has been publishing ANS estimates for all countries for which these data are

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[72] The concept of weak sustainability (WS) is rooted in the argument that natural capital and produced capital are similar and infinitely substitutable. This notion of WS 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 to establish a rule on how much of it to consume and how much should be reinvested in produced capital for future consumption.

available starting from 1970. A detailed description of the components of ANS and how it is calculated is provided in appendix A1.

7.2.2 What is subjective well-being?

Well-being results from a set of factors that are required for a flourishing life. Well-being may be understood subjectively or via a range of observed (objective) social indicators. The definition of well-being varies across people, groups and disciplines (Galloway et al., 2006, Higgins, 1997, Roberts et al., 2013). For instance, Huppert, Baylis, & Keverne (2004), on page 1331, define well-being as *"a positive and sustainable state that allows individuals, groups or nations to thrive and flourish"*. According to Defra (2009), on page 119, well-being *"is understood to be a positive physical, social and mental state; it is not just the absence of pain, discomfort and incapacity. It requires that basic needs are met, that individuals have a sense of purpose, that they feel able to achieve important personal goals and participate in society. It is enhanced by conditions that include supportive personal relationships, strong and inclusive communities, good health, financial and personal security, rewarding employment, and a healthy and attractive environment."*

There are several concepts of well-being which are categorised into two broader categories, objective well-being and subjective well-being (SWB). The former broadly deals with material measures of well-being (such as income, longevity, etc.) and the latter focuses on people's self-reported happiness and satisfaction of life (Cummins, 2012, Gleisner, Llewellyn-Fowler, & McAlister, 2011, MacKerron, 2012, Roberts et al., 2013, Waldron, 2010).

There is a range of contributors to well-being discussed in different disciplines. For instance, economics traditionally understands well-being as an outcome of utility maximization subject to constraints. Hence a person with higher income can have more goods and services leading to higher levels of satisfaction (Green, 2013, Jackson, Jager, & Stagl, 2004, MacKerron, 2012). This approach implies that the relationship of happiness (i.e. utility) to income exhibits diminishing returns and several papers have confirmed this relationship (Cummins, 2012, Dodds, 1997, Easterlin et al., 2010, Frey & Stutzer, 2002, J. F. Helliwell, 2003, Jackson, Jager, & Stagl, 2004, Schwartz et al., 2002, Veenhoven, 1995). In a recent New Zealand focused study, Sengupta et al. (2012) found the same relationship for New

Zealanders. Their key finding was that there was a robust relationship between income and happiness for annual incomes from 10,000 NZD to 30,000 NZD. This relationship becomes less responsive and tends to plateau beyond an average annual income of 65,000 NZD, while increases in income beyond 125,000 NZD had insignificant incremental effect on happiness.

Subjective well-being studies examine the subjective feeling of the subject regarding her happiness, unhappiness, and satisfaction with life through different survey questions (Dodds, 1997, Frey & Stutzer, 2002, Jamison, 2008, Schwartz et al., 2002, Waldron, 2010). The Gallup Poll[73], Eurobarometer Surveys[74], European Values Surveys (EVS)[75], General Social Surveys (GSS)[76], and World Values Surveys (WVS)[77] are examples of such surveys conducted internationally.

Happiness and life-satisfaction have sometimes been used interchangeably in the literature; however there is a clear distinction between them. According to Diener et al. (2010), people tend to correlate life-satisfaction with material prosperity when they answer how satisfied they are with their lives whereas they tend to correlate happiness with social prosperity once they have all their basic needs met. Most studies in the economics literature concentrate on life-satisfaction rather than on (shorter term) happiness. By contrast, studies in psychology tend to concentrate more on the attainment/presence of happiness or avoidance/absence of pain; and/or on the eudaimonic approach to well-being, which defines well-being in term of how a person is functioning in her life (Deci & Ryan, 2008, J. Helliwell, Layard, & Sachs, 2012, Konow & Earley, 2006, Ryan & Deci, 2001).

7.2.2.1 Factors affecting well-being

The social context in which well-being is defined, referenced, perceived, or applied has significant impact on the extent and interpretation of well-being (Diener, Lucas, & Oishi, 2002). What is considered desirable varies from person to person, society to society and religion to religion. It may also vary with age, social status, sexual orientation, marital status and so on within the same society. One focus of empirical

[73] http://www.well-beingindex.com/
[74] http://ec.europa.eu/commfrontoffice/publicopinion/index.cfm
[75] http://www.europeanvaluesstudy.eu/
[76] http://www.norc.org/Research/Projects/Pages/general-social-survey.aspx
[77] http://www.worldvaluessurvey.org/wvs.jsp

research on individual well-being has been identifying the determinants of happiness among various population groups. This research shows a considerable degree of consensus across survey locations, on key determinants of happiness which include age, sex, cultural affiliations, happiness of relatives and friends, strengths of social network, and marital status (Brown & Tierney, 2009, Frey & Stutzer, 2002, Gross et al., 1997).

A number of studies including Dengah (2014) and Brown & Tierney (2009) also find that religiosity demonstrates strong correlation with well-being and happiness particularly among elderly people. Brown & Tierney (2009), for instance, argue that religion has greater impact on the SWB of men than that of women. In faith based communities, people provide support to each other in the face of vulnerabilities so religious people tend to rebound from divorce, illness, unemployment etc.; religion may also foster higher expected utility from a belief in the hereafter (Azzi & Ehrenberg, 1975, Ellison, Gay, & Glass, 1989, Ellison, 1991).

Well-being research from social psychology underpins numerous factors explaining why societies may differ in terms of well-being. A culture shapes personality in a number of ways which influence an individual's realization of well-being (Tiberius, 2004). Other key factors responsible for shaping personality are wealth and self-serving biases[78] such as self-assessment, self-enhancement, self-criticism etc. (Diener, Oishi, & Lucas, 2003). Wealthier nations score higher on human rights, equality, justice, democratic governance etc. implying a positive relationship between well-being and these aspects of human rights (Biswas-Diener & Diener, 2001, Diener, Oishi, & Lucas, 2003).

Strength of social networks is also seen as a determinant of well-being which may vary across groups (Ellison, Gay, & Glass, 1989, J. F. Helliwell & Putnam,

[78] Self-serving biases are deviations from reality in which respondents tend to report overestimated or underestimated facts. For example, researchers have found that East Asians are weaker in self-enhancement (a self-serving bias in which one rates herself better compared to how she rates others) compared to Americans, whereas, they tend to have high self-criticism tendencies (Heine, Takata, & Lehman, 2000, Heine et al., 1999). Oishi & Diener (2003) found that European Americans tend to overestimate the number of anagrams they solved last week whereas, Asian American underestimate this number. Dockery (2010) argues that indigenous culture should be viewed as a part of well-being enhancement and not as part of a problem.

2004, Kettner, Köppl, & Stagl, 2012). However, various type of social networks may have different correlations with well-being. For instance, Helliwell & Putnam (2004) found a robust and independent relationship between social capital and SWB through family ties, relationship with neighbours, friends and relatives etc. However, no significant correlation has been proven between ethnic homogeneity in an internet based friendship network (e.g. facebook) and SWB (Seder & Oishi, 2009).

Similarly, ethnic diversity is believed to affect well-being by influencing people's preferences and behaviours. In America, for example, housing prices in a neighbourhood with a more homogeneous minority population are higher than in more diverse neighbourhoods (Li, 2014). Ethnic diversity is also found to impact behaviours in developing countries. In sub-Saharan Africa, public good provisioning such as funding for primary education is strongly associated with ethnicity, while public schools in Kenya that have high ethnic diversity receive much lower funding than largely homogenous schools (Miguel & Gugerty, 2005).

In the empirical models of our study, we control for both personal and country level factors to study well-being. Personal level variables include age, sex, marital status, employment status, income scale and education levels. Country level variables include internationally comparable GNI per capita in terms of purchasing power parity (PPP), inflation rate and unemployment rate as these variables are suggested to have strong relationships with SWB (Gnègnè, 2009, Grimes et al., 2016, Novak & Pahor, 2017, Tella, MacCulloch, & Oswald, 2001, Welsch & Kühling, 2016).

7.2.3 Possible relationships between ANS and SWB

The relationship between the individual components of ANS such as natural capital, human capital, produced capital and its rate of return (measured by income per capita) and SWB has been extensively studied in the literature. The predictive power of ANS to explain changes in national level well-being – but not individual level well-being – has also been examined.

Well-being may be analyzed at both individual and aggregate levels (e.g.

regional or national aggregates) as an outcome of individual traits[79] and a range of national level indicators[80]. We can postulate eight possible combinations of relationship between ANS and SWB (or other measures of well-being) as summarized in Table 1 (where Δ signifies a change in that variable across time).

Table 1: Possible model specifications (each controlling for other variables)

Dependent variable / Independent variable(s)	Individual level	Aggregate level
SWB / ANS	X	X
SWB / ΔANS	X	X
ΔSWB / ANS	X	X
ΔSWB / ΔANS	X	X

In other words, the relationship between SWB and ANS can be modelled at individual or country level, with one or both variables expressed either in levels or changes. A summary of existing literature relevant to this subject in terms of the above combinations is presented in Table 2.

Examining Table 2, we observe two groups of studies: 1). First, ANS (or its variants i.e. GS, CI, CW) has been used as a predictor of changes in future well-being at national level (Greasley et al. (2016), Hanley et al. (2016), Greasley et al. (2014), Blum, McLaughlin, & Hanley (2013), Gnègnè (2009)). Ferreira, Hamilton, & Vincent (2008) have used GS to predict changes in future real consumption per capita which has been used as a proxy for national level well-being.

Second, all SWB studies for individual or aggregate country level models are formulated using both the dependent variables and the explanatory variables at levels (rather than changes)[81]. To the best of our knowledge, none of the papers has applied ANS or any of its variants to predict future individual level SWB while controlling also for past levels of SWB. However, the literature on cultural and other determinants of SWB show that it is vital to control for SWB levels across different countries and cultures, so studies that omit this country-specific aspect are

[79] Key individual traits collected in WVS or EVS include age, sex, education level, employment status, marital status, income level, religious affiliation etc.
[80] National level indicators including both single indicators (e.g. GDP, GNP etc.) and composite indicators (such as HDI, GS, ANS etc.). For details see Qasim (2017).
[81] Using current variables at levels may induce the risk of endogeneity in the results. This problem is elaborated further in the methodology part together with our mitigation strategy.

likely to be flawed. The present paper is the first to fill this gap.

Table 2: Key studies including well-being and ANS or its individual components (recent to older)

Reference	Dependent variable(s)	Independent variable(s) in one or more models	Type of study LHS vs RHS	Scope of study
Novak & Pahor (2017)	SWB	GNI per capita, Unemployment rate, inflation, relative income, unemployment, gender, marital status, number of children, health, education, age, immigrant, democracy	Levels – Levels	Individual level
Greasley et al. (2016)	PVΔC	Net national investment, Green investment, comprehensive investment (GS, ANS), Cl adjusted for minerals, CI adjusted for TFP	Changes – Levels	Country level
Grimes et al. (2016)	SWB	Fiscal variables, personal controls	Levels – Levels*	Individual level
Hanley et al. (2016)	PVΔC	GS, GS adjusted for TFP	Changes – Levels	Country level
Grimes & Reinhardt (2015)	SWB	Respondent income, mean income of others, relative gross national disposable income	Levels – Levels*	Country level
Greasley et al. (2014)	PVΔC, PVΔW	GS and its individual components	Changes – Levels	Country level
Blum, McLaughlin, & Hanley (2013)	PVΔC	GS and its individual components	Changes – Levels	Country level
Engelbrecht (2012)	SWB	Total wealth per capita, GNI per capita, natural capital per capita, produced capital, intangible capital	Levels – Levels	Country level
Verme (2011)	SWB	income, income inequality, relative income, country's wealth, age, sex, education, trust, work, politics, religion	Levels – Levels	Individual level
Pittau, Zelli, & Gelman (2010)	SWB	personal income, national income, age, sex, education, employment, marital status	Levels – Levels	Country level
Engelbrecht (2009)	LS, Happiness, SWB Index	Natural capital per capita, GNI per capita, Trust variable, Gini coefficient, Unemployment, inflation	Levels – Levels	Country level
Gnègnè (2009)	ΔHDI ΔIMR	ANS per capita, NNS per capita, ANS_E, ANS_P, ANS EP, Initial income, Initial life expectancy, Initial school, Public consumption, Trade, Gastil index	Changes – Levels	Country level
Bonini (2008)	LS	HDI, ESI, GDP per capita, Age, education, sex	Levels – Levels	Individual level
Ferreira, Hamilton, & Vincent (2008)	PVΔC	Gross savings, Net savings, Green savings, Population adjusted savings, Population growth rate Total population	Changes – Levels	Country level
Vemuri & Costanza (2006)	LS/SWB	HDI, ESP per squared km index, Press freedom	Levels – Levels	Country level
Leigh & Wolfers (2006)	SWB, Happiness	HDI, GDP per capita	Levels – Levels	Country level
Schyns (2002)	SWB	income at low medium and high levels, national income	Levels – Levels	Country level

Footnotes:
* Individual level study with cross-sectional country fixed effect added.
GS and CI: Genuine savings and comprehensive investment (these are alternative terms for ANS).
TFP: Total factor productivity.

PVΔC: Present values (PV) of changes in per capita consumption in real-terms.
PVΔW: PV of changes in real wages per capita. PVΔC and PVΔW are used as a proxy for aggregate objective well-being.
ΔHDI: Change in human development index.
ΔIMR: Change in infant mortality rate
ANS_P: ANS calculated without CO2 damage.
ANS_E: ANS calculated without education expenditure.
ANS_EP: ANS calculated without CO2 damage and education expenditure.
ESI: Environmental sustainability index.
GNI: Gross national income
NNS: Net national savings.
LS: Life-satisfaction from the WVS. This is referred to as SWB in our paper.
ESP: Ecosystem services product.

7.2.4 Components of ANS and SWB

Research on the relationship between particular components of ANS and SWB has been conducted since the early 1970s (Land & Michalos, 2017). This includes work on the relationship between income and happiness (Easterlin, 1974, 2005, Easterlin et al., 2010, R. D. Tella & MacCulloch, 2008), Grimes & Reinhardt (2015), Verme (2011), Schyns (2002) and Pittau, Zelli, & Gelman (2010)). Many of these studies find that if all residents within a country has the same proportionate increase in income then no-one feels better-off since all relativities remain unchanged. This is known as the Easterlin Paradox. However, other income and happiness studies such as Leigh & Wolfers (2006) and Stevenson & Wolfers (2008) have shown that the Easterlin Paradox does not exist and an increase in income does result in higher life-satisfaction.

Significant work has been undertaken to explain SWB using composite indicators including natural capital, produced capital and human capital components. For instance, Leigh & Wolfers (2006) analyzed the relationship between the Human Development Index (HDI) and individual happiness using a WVS dataset of 115,000 individuals from 32 countries. Their results suggested that, in general, people from countries with high HDI are happier. In another study on the same relationship, Blanchflower & Oswald (2005) have shown a few exceptional countries, such as Australia, that have high HDI but lower average happiness scores which they call an HDI happiness paradox. Vemuri & Costanza (2006) also used HDI (as a proxy for human capital and produced capital) with an index for ecosystem services per square kilometer (as a proxy for natural capital) in their model for 57 countries to explain the relationship between SWB (using WVS data) and various types of capitals (e.g. human capital, produced capital, natural capital). Their results suggested that combinations of these capitals can explain 72%

of the variation in individuals' life-satisfaction. Engelbrecht (2009) also found a positive and significant relationship between natural capital and the levels of individual life-satisfaction. However, these latter studies use levels of each of the series which may yield distorted conclusions.

Bonini (2008) analyses the variation in the individual life-satisfaction of 76,038 individuals from 63 countries using a WVS dataset. A key finding of this study is that individual life-satisfaction differs significantly across countries and regions and that slope coefficients also differ across countries; therefore, universal development indicators may not adequately cover the policies required to address well-being across countries. Grimes et al. (2016) explored the association between fiscal policies and SWB using data for over 170,000 individuals from 35 countries and find that distortionary taxes (e.g. income tax) are positively associated with SWB compared to non-distortionary taxes (e.g. sales tax).

Finally, ANS itself has been widely adopted as a predictor of aggregate objective well-being. For example, the changes in the discounted value of real consumption per capita as a proxy for aggregate objective well-being has been explained using GS/ANS/CI/IW by (Blum, McLaughlin, & Hanley, 2013, Ferreira, Hamilton, & Vincent, 2008, Greasley et al., 2016, Hanley et al., 2016). Similarly, Greasley et al. (2014) took real wages per capita as a proxy for objective well-being to study the explanatory power of GS. A summary of other relevant literature is presented in Table 3.

Table 3: Summary of related SWB literature

Title/Reference	Data	Study type/design	Models
Novak & Pahor (2017) Using a multilevel modelling approach to explain the influence of economic development on the subjective well-being of individuals	WVS survey 2005 – 2009 Data for 49 countries from From the World Bank Development Indicators	Individual level study Cross-sectional data	Multilevel modelling
Gnègnè (2009) Adjusted net saving and welfare change	Data for 36 Countries From the World Bank HDI data from UNDP	Country level study Panel data Variables at difference	Regression models
Bonini (2008) Cross-National Variation in Individual Life-satisfaction:	WVS 1999 – 2003 76,038 Adults 63 countries*	Individual level study Cross-sectional data Variables at levels	Multilevel modelling

Effects of National Wealth, Human Development, and Environmental Conditions	HDI from UNDP 2000 ESI from CIESIN 2001		
Vemuri & Costanza (2006) The role of human, social, built, and natural capital in explaining life-satisfaction at the country level: Toward a National Well-Being Index (NWI)	WVS 1990 – 1995 57 countries Proxies for data on 4 types of capitals from UNDP for 171 countries Freedom house press (1999)	Country level study Cross-sectional data Variables at levels	Regression models
Ferreira, Hamilton, & Vincent (2008) Comprehensive Wealth and Future Consumption: Accounting for Population Growth	1970 – 1982 Data for 64 Countries From the World Bank Development Indicators	Country level study Panel data Country fixed effect	Regression models
Engelbrecht (2009) Natural Capital, SWB, and the New Welfare Economics of Sustainability: Some Evidence from Cross-Country Regressions	WVS 2005 58 countries Natural capital data from the World Bank's Millennium Capital Assessment	Country level study Cross-sectional data Variables at levels	Regression models
Grimes et al. (2016) Subjective Wellbeing Impacts of National and Subnational Fiscal Policies	35 countries 130 years 170,000 individuals' SW IMF Govt. Financial Statistics 2014 with OECD data to fill missing data WVS 2014	Individual level study Panel data Country fixed effect Time fixed effect	Regression models
Grimes & Reinhardt (2015) Relative Income and Subjective Wellbeing: Intra-national and Inter-national Comparisons by Settlement and Country Type	WVS 1990 – 2009 27 countries 16 OECD and 11 others 68 cross-sections 78,058 individuals	Country level study Panel data Country fixed effect Time fixed effect	Regression models
Verme (2011) Life-satisfaction and Income Inequality	WVS 1981 & 2004 267,870 individuals 1,349 regions 84 countries IMF: GDP, PPP UNU–WIDER: inequality	Individual level study Panel data Country fixed effect	Regression models
Leigh & Wolfers (2006)	WVS 2005 78 countries 115,000 individuals Happiness ISSP 2002	Country level study Cross-sectional data Variables at levels	Regression models

Happiness and the Human Development Index: Australia Is Not a Paradox	32 countries 50,000 individuals HDI		
Engelbrecht (2012) Some empirics of the bivariate relationship between average SWB and the sustainable wealth of nations	WVS 1990 – 2002 World Bank 2006	Country level study Cross-sectional data Variables at levels	Regression models
Schyns (2002) Wealth of Nations, Individual Income and Life-satisfaction In 42 Countries: A Multilevel Approach	WVS 1990 42 countries 50,046 individuals	Both individual and country level study Panel data Country fixed effect	Multilevel OLS
Pittau, Zelli, & Gelman (2010) Economic Disparities and Life-satisfaction in European Regions	1970 – 2002 Eurobarometer surveys 15 EU countries 1.1 million respondents	Both individual and country level study Panel data Country/regions fixed effect	Multilevel Models
Greasley et al. (2016) Australia: A land of missed opportunities?	1870 – 2011 Australia	Country level study Single country study Time-series data Dependent variable as change in value	Regression models
Hanley et al. (2016) Empirical testing of Genuine Savings as an indicator of weak sustainability: a three-country analysis of long-run trends.	1870 – 2008 for Britain USA Germany	Country level study three country study Time-series data Dependent variable as change in value	Regression models
Greasley et al. (2014) Testing genuine savings as a forward-looking indicator of future well-being over the (very) long-run	Britain 1760 - 2000	Country level study Single country study Time-series data Dependent variable as change in value	Regression models
Blum, McLaughlin, & Hanley (2013) Genuine savings and future well-being in Germany, 1850-2000	Germany	Country level study Single country study Time-series data Dependent variable as change in value	Regression models

To the best of our knowledge, ANS has not been applied to study changes in SWB of individuals across countries. Consistent with the recommendations of Stiglitz, Sen, & Fitoussi (2010) we consider it important to focus on individual (or household) well-being, rather than on aggregate measures of well-being. For methodological reasons, we also consider it important to focus on changes in well-being (rather than on levels). The present work, which examines the effects of a country's ANS on changes in its residents' SWB, aims to fill these gaps.

7.2.5 Hypothesis

Consistent with studies that analyse the aggregate relationship between ANS and certain well-being indicators, we hypothesize that countries with higher levels of ANS perform better, in the long-run, in terms of changes in SWB of their inhabitants. The reason underlying this hypothesis is that the countries which save more (in a comprehensive sense) are better able to have resources available, in the long term, to promote the well-being of future citizens. We aim to test this hypothesis using three different regression-based models discussed in the following section.

7.3 Methods

The main aim of this paper is to test whether ANS helps to predict future SWB outcomes. In order to isolate this effect, we control for a set of variables which have been shown in the previous literature to have high explanatory power for SWB. Equation (1) illustrates a baseline model. SWB for individual i in country c at time t is expressed as a function of M, a vector of macro-controls, X, a vector of personal controls, ANS, wave (time) fixed effects λ_w, and country fixed effects λ_c:

$$SWB_{i,c,t} = \beta_0 + \beta_1 M_{c,t} + \beta_2 X_{i,t} + \beta_3 ANS_{c,t} + \lambda_w + \lambda_c + \epsilon_{i,c,t} \qquad (1)$$

where:

SWB	subjective well-being
i	individual
c	country
t	time
M	vector of macro controls
X	vector of personal controls
ANS	adjusted net savings
λ_c	country fixed effect
λ_w	time (wave) fixed effect

One potential problem with equation (1) is that this model may be subject to an endogeneity problem due to simultaneity (or omitted variables). For example, ANS at any given time for a country potentially has a strong relationship with its current level of income, and thence its current SWB. For this reason, while this model is our own starting point, we do not attempt to interpret its (likely biased) results. (For completeness, we report its results in Table A2.6.1 in the appendix.) In model (2) we attempt to mitigate the endogeneity problem by modifying model (1) utilising the timing of our variables. We will focus on the results of this model in the later sections.

$$SWB_{i,c,t1} = \beta_0 + \beta_1 M_{c,t0} + \beta_2 X_{i,t1} + \beta_3 ANS_{c,t0} + \beta_4 SWB_{c,t0} + \epsilon_{i,c,t1} \quad (2)$$

Equation (2) represents a cross-sectional model (and hence excludes country and wave fixed effects) in which $t1$ is the *'end-wave'* and $t0$ is the *'initial-wave'* for a particular country group. For example, (as discussed in section 4) for Group 1 countries, $t1$ is wave 4 and $t0$ is wave 2 of the WVS. Thus, we are regressing individual SWB in wave 4 on personal characteristics of those same individuals in wave 4 and on country variables (M, ANS and aggregate SWB) from wave 2. This model indicates how the initial ANS affects subsequent individual SWB after controlling for initial levels of a country's SWB. The need to control for a country's initial mean level of SWB – which has not been done in the prior SWB studies summarised in Table 2 and Table 3 (other, implicitly, than those that include individual country fixed effects) – is shown to be important in the studies summarised in section 2.2.1. We also estimate the per annum change in SWB aggregated to several age and sex groups in model (3) to conduct a pseudo-panel analysis that links changes in SWB of types of people to the initial SWB of that person type.

$$\frac{\Delta SWB_{gct}}{\#Years} = \beta_0 + \beta_1 SWB_{gct0} + \beta_2 M_{c,t0} + \beta_3 ANS_{ct0} + \lambda_g + \epsilon_{gct} \quad (3)$$

where, *#Years* is the length of period (in years) between two waves of WVS for each group, so coefficients can be interpreted as per year effects on SWB changes of the RHS variables, g represents group averages.

The following four groups are defined based on age and sex:
Age-sex group 1 & 2: 15 – 29 years old male/female
Age-sex group 3 & 4: 30 – 44 years old male/female
Age-sex group 5 & 6: 45 – 59 years old male/female
Age-sex group 7 & 8: 60 + years old male/female

We dropped any country which does not have any observations for each group in each time-period. For example, Brazil does not have any data for individuals over 60 years old in the 2nd wave of WVS, and therefore is dropped from the data. The number of individuals in each group by country and by wave are summarised in Table A2.5.

The World Bank provides estimates for two variants of ANS: (1) ANS excluding emission damage from particulate matter (% of GNI)[82]; (2) ANS including emission damage from particulate matter (% of GNI)[83]. We estimated all of our models for both of these variants. While SWB is a categorical (ordered) variable, it is common to treat SWB as if it were a cardinal variable and to estimate SWB models using OLS (Ferrer-i-Carbonell & Frijters, 2004, Luttmer, 2005) given that results have been found to be similar when estimating using OLS and ordered logit. Given this tradition, we estimate model (2) using each of OLS and ordered logit. Equation (3) is estimated using OLS.

7.4 Data

7.4.1 SWB and personal controls

Self-reported subjected well-being and data on personal controls[84], such as age, sex,

[82] Adjusted net savings are equal to net national savings plus education expenditure and minus energy depletion, mineral depletion, net forest depletion, and carbon dioxide. This series excludes particulate emissions damage.
[83] This series includes carbon dioxide and particulate emissions damage. See A1 for detailed noted on the calculation of ANS.
[84] Personal controls include age, sex, marital status, employment status, income level and education; and all WVS questionnaires include this information. The order of questions against which this information is recorded is different in different waves and we adjusted the data accordingly.
Another major challenge in processing WVS data is the use of different scales to record the answer of same questions. For example, the question on marital status is recorded as one of the following responses in wave 2 and wave 6:
-5: Missing; Unknown; Inappropriate; -4: Not asked; -3: Not applicable; -2: No answer; -1: Don't know; 1: Married; 2: Living together as married; 3: Divorced; 4: Separate; 5: Widow; 6: Single
The same questions have two additional categories of responses in wave 4 and wave 5 which are:
7: Divorced, separated or Widow; 10: Living apart while married/cohabitation.

marital status, employment status, income level and education were downloaded from WVS website[85] for waves 2,4,5 and 6[86]. The surveys are conducted in each country with domestic funding using stratified multistage random sampling, national random sampling or quota sampling methods. All WVS surveys are conducted in the national language with face-to-face interviews (Donnelly & Pop-Eleches, 2012). The SWB question is asked in the local language as:

> *All things considered, how satisfied are you with your life as a whole these days? Using this card on which 1 means you are "completely dissatisfied" and 10 means you are "completely satisfied" where would you put your satisfaction with your life as a whole? (Code one number): Completely dissatisfied 1 2 3 4 5 6 7 8 9 10 Completely satisfied.*

SWB is tightly distributed across all countries and all groups, with a mean of 6.7, median 7.0 and standard deviation of approximately 2.4. Hence a small change in its value can be economically material. Figure A1 shows the distribution of SWB by income levels by WVS wave in each group. General trends in the data reveal that higher income levels are associated with higher levels of SWB. Further details on the data from WVS are provided in table A2.1. of the data appendix. The number of individuals surveyed in each wave by country is summarised in Table A2.4.

WVS data have been criticised for inconsistencies of data categorization for the same variable across different waves. Income distribution, for instance, associated with ten categories are not income deciles, as interpreted by some researchers, and the method to record them also varies across different waves (Donnelly & Pop-Eleches, 2012, Grimes & Reinhardt, 2015, Grimes et al., 2016). In the majority of surveys, respondents are asked to place themselves in one of ten income brackets (e.g. $1 – $1,000, $1,000 – $5,000 etc.) where these income brackets are pre-determined by WVS. Donnelly & Pop-Eleches (2012) noted that the documentation

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Such data inconsistencies make the careful re-coding of data imperative prior to conduct any further analysis. Detailed notes on data preparation and re-coding are provided in the Data Appendix table A2.1.

[85] http://www.worldvaluessurvey.org/WVSContents.jsp last visited on 19/08/2017.

[86] Wave years: Wave 2: 1990–94; Wave 4: 1999–04; Wave 5: 2005–09; Wave 6: 2010–14.

for some income brackets for a number of countries were missing. As a result, these brackets do not generate a uniform distribution of income. In other cases, respondents are asked to place themselves on a 1 to 10 income scale, 1 being the lowest and 10 being the highest decile income group. In such cases, most of the people tend to report a central number. For example, 84% of Americans in the 2006 wave reported they are in one of the 5 middle deciles (i.e. 3 – 7) (Grimes et al., 2016). In some cases, respondents are asked to report their actual income which is later translated into a 1 to 10 scale.

Because of these data inconsistencies, we interpret income level as an ordinal variable within each data group (discussed under the following section) i.e. if somebody falls in a higher income level that person is likely to earn more. However, the cardinal relationship between income categories is not known. Since income is a control variable, rather than a direct variable of intent, in this study we do not attempt to interpret the income parameters.

7.4.2 ANS and other country level variables

Data for the key independent variable ANS and other country level variables i.e. real GNI per capita in PPP, inflation rate, and unemployment rate were downloaded from the World Bank's World Development Indicators Database (WDI). This dataset is provided in Table A2.3 (see data appendix for URL and variable details).

We divided the final dataset into four separate groups for our analysis. Each group includes SWB data from two different waves of WVS for all countries which are covered in both waves and that have ANS data from the World Bank. The composition of these data groups is given in Table 4.

Table 4: Composition of data groups

Data group	WVS Waves & no. of respondents	Duration between waves	Countries included
1.	Wave 2: 14,904 respondents Wave 4: 17,733 respondents	approx. 10 years	**10 countries:** Argentina, Chile, China, India, Mexico, Nigeria, South Africa, South Korea, Spain, Turkey
2.	Wave 2: 17,077 respondents Wave 5: 16,831 respondents	approx. 15 years	**11 countries:**

			Argentina, Brazil, Chile, China, India, Mexico, South Africa, South Korea, Spain, Switzerland, Turkey
3.	Wave 2: 16,674 respondents Wave 6: 21,035 respondents	approx. 20 years	**11 countries:** Argentina, Brazil, Chile, China, India, Mexico, Nigeria, South Africa, South Korea, Spain, Turkey
4.	Wave 4: 33,664 respondents Wave 6: 36,316 respondents	approx. 10 years	**21 countries:** Algeria, Argentina, Chile, China, Egypt, India, Japan, Jordan, Kyrgyzstan, Mexico, Morocco, Nigeria, Pakistan, Peru, Philippines, Singapore, South Africa, South Korea, Spain, Sweden, Turkey, United States

In our regression models, age is a continuous variable and both age and age squared are included to capture the curvilinear effect of age on SWB. Sex, marital status, employment status, income level and education levels are coded as dummy variables. Reference groups for these variables are males, employed, lowest income step, and no formal education respectively. In the result tables, these variables have the following identity prefixes sex_, ms_, es_, in_, and ed_ respectively. We also included dummies for missing entries for these variables and a dummy for missing age in our estimates.

For the pseudo-panel models, we split the dataset into 8 groups of panel data based on age and sex. The count of observations in each group and in each wave is summarised in table A2.5. These groups are defined in section 3.

We dropped 107 observations from the final group level dataset where data for age and sex were not available. Brazil was excluded from group 2 and 3 as it does not have any observations for individuals over 60 in WVS wave 2. In the result tables of pseudo-panel models, the 15 – 29 year old female group is the reference group.

7.4.3 Handling missing values

ANS

A few countries covered in WVS do not have ANS data for the same year from the World Bank. In such a case where a country does not have an ANS estimate for the year it was surveyed for WVS, we used the ANS values from the next or previous year. Any country which does not meet this condition was dropped from the dataset resulting in the following omissions:

- Japan was dropped from group 1, 2 and 3;
- Russia was dropped from group 2 and 3;
- Belarus was dropped from group 3;
- Iraq and Zimbabwe were dropped from group 4;
- Algeria was dropped from group 4;

Unemployment

Unemployment data series start from 1991 for all countries in WDI data. Therefore, we used 1991 values for the following countries which were surveyed in 1990 by WVS. Chile, China, India, Mexico, Nigeria, South Africa, South Korea, Spain, Switzerland, Turkey

GNI (PPP)

A GNI series for China was not available from the World Bank Data Bank. It was sourced from UNDP's data website: http://hdr.undp.org/en/data on a consistent basis with the World Bank's data.

7.4.4 Summary Information

Before estimating our models, we plot the relationship between SWB and income levels recorded in WVS as shown in Figure A2.1. As expected, higher income, on average, is associated with higher levels of SWB across all waves of WVS. However, this relationship appears non-linear. An increase in income from lowest step towards the middle step (i.e. from lowest step to step five) results in a larger increase in SWB than beyond that level of income. Similarly, we observe a direct and positive relationship between SWB and real PPP-adjusted GNI per capita in Figure A2.2. These results are intuitive and consistent with the results of many other similar studies such as (Engelbrecht, 2009, 2012). These patterns reinforce the results by Pittau, Zelli, & Gelman (2010) that personal income matters more in poor countries than in rich countries. Summary data descriptive information is included in Tables A2.3 – A2.5.

7.5 Results and discussion

Coefficients on ANS for all four groups in both model (2) and model (3) are summarised in Table 5. Full model 2 results using OLS are summarised in Tables 6 – 9 while the model (3) results are presented in Tables 10 – 13. In general, the results for the control variables are intuitive and consistent with the results of previous studies. In individual controls, for instance, we observe age exhibiting a non-linear and significant relationship with SWB. In the beginning, age is negatively correlated with SWB and after a certain age, this relationship is reversed. This result confirms the findings of Gross et al. (1997) and Carstensen et al. (2000) that young and older people are happier than mid-aged.

It is a general perception that women might have lower levels of life-satisfaction because they have access to fewer resources and traditionally possessed less power, freedom and status than men (Diener & Diener, 2009). However, many studies have found no or negligible differences between the SWB of men and women (Headey & Wearing, 1992, Herzog, Rodgers, & Woodworth, 1982, Schyns, 2002). Our estimates also show mixed results for sex. Women have positive SWB in the results of group 1 and group 2, but the relationship is insignificant in the results of group 3 and 4. Another interesting finding is that the housewife group is significantly more satisfied than any other group in the employment status category (especially in groups 1 and 4).

Higher levels of both income and education are significantly and positively related to SWB in all four cases of model (2). Similar results have been shown by others (Diener & Biswas-Diener, 2002, 2002, Schyns, 2002). Another consistent finding is that the magnitude of increase in life-satisfaction in response to increases in income exhibits a concave pattern. In other words, an increase in income is associated with higher SWB, however, with diminishing returns. Finally, our results show higher levels of average SWB in the first period is directly and significantly associated with higher life-satisfaction of individuals in the following period in 3 of the 4 models, while it has a negative significant association for group 2. This shows the criticality of including a control for prior SWB in any study of the relationship of another variable of interest (ANS in our case) with SWB; many prior studies have failed to do so.

In terms of macro controls, the relationship between initial ppp-adjusted real GNI per capita and subsequent life-satisfaction is positive and significant. Initial unemployment rates are negatively associated with subsequent SWB across all groups, while the coefficient of initial inflation shows a positive relationship with SWB in all cases except group 1 where the coefficients are not significant[87].

In general, coefficients of macro controls for Model (2) using both OLS (Table 6 – 9) and ordered logit models (Table A2.7.1 – A2.7.4) are consistent in terms of signs and significance levels. Each of these macro variables is included to control for prevalent economic conditions across countries, and so we do not attempt to interpret their estimated coefficients. However, as with initial SWB, the significance of the (initial period) macro controls demonstrates the importance of controlling for (prior) country-specific factors when assessing the relationship between ANS and SWB, which has often been overlooked in cross-sectional studies.

Now we turn our focus to Table 5 to interpret the relationship of (future) life-satisfaction to the two variants of initial ANS (i.e. ANS including PM and ANS excluding PM). In both models, we observe that higher initial levels of ANS (in each of its variants) is negatively associated with future SWB over time horizons of 10 – 15 years with this relationship being significantly negative in 15 out of 18 cases. By contrast, the relationship is positive over the longer time horizon (i.e. 20 years in the group 3 results), and are significantly so using the cross-sectional OLS models.

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[87] Tella, MacCulloch, & Oswald (2001) finds that inflation has negative effect on SWB for European countries for the period 1975–1991, whereas the results for US are not clear. Welsch & Kühling (2016) find that lower inflation rates reduced the negative effect of the economic crisis, while Novak & Pahor (2017) has found that inflation rate does not have a significant effect on subjective well-being.

Table 5: Coefficients of ANS variables

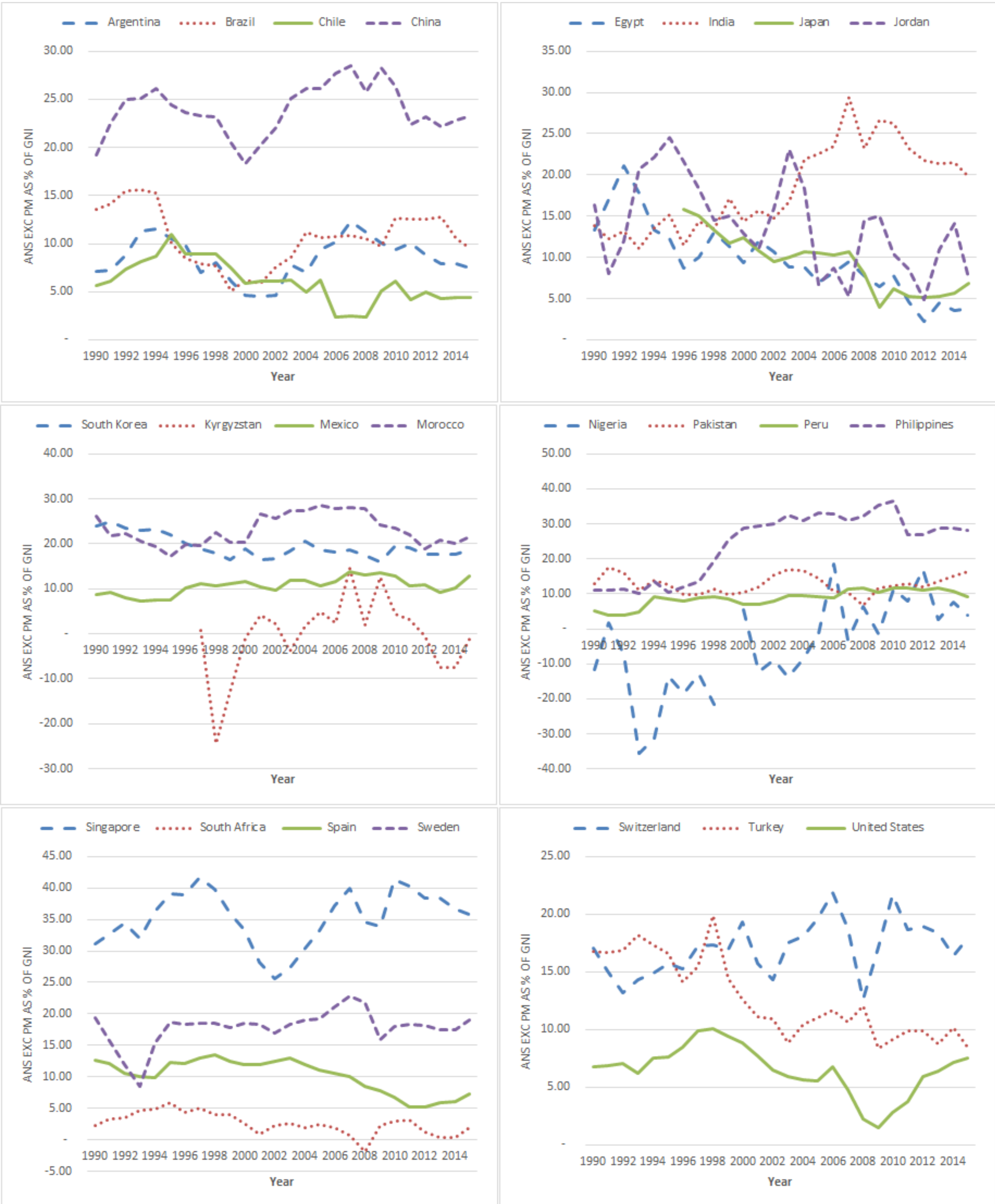
	Group 1 **Wave 2 & 4** **≈10 years**	Group 2 **Wave 2 & 5** **≈15 years**	Group 3 **Wave 2 & 6** **≈20 years**	Group 4 **Wave 4 & 6** **≈10 years**
Model 2: Cross-sectional models (using OLS)				
ANS inc. PM	-0.03***	-0.04***	0.01***	-0.01***
ANS exc. PM	-0.04***	-0.05***	0.01***	-0.005***
Model 2: Cross-sectional models (using ordered logit)				
ANS inc. PM	-0.03***	-0.04***	0.001	-0.01***
ANS exc. PM	-0.03***	-0.05***	0.001	-0.01***
Model 3: Pseudo-panel models (OLS)				
ANS inc. PM	-0.005***	-0.001	0.0003	-0.001
ANS exc. PM	-0.01***	-0.001*	0.0003	-0.001

Note: *p<0.1; **p<0.05; ***p<0.01

Before going into further interpretation, it is important to note two key characteristics of ANS: (1) it has been emphasised that ANS is a comprehensive sustainability measure for infinite time horizons (Blum, McLaughlin, & Hanley, 2013, Ferreira, Hamilton, & Vincent, 2008, Ferreira & Vincent, 2005, Greasley & Madsen, 2016, Greasley et al., 2014, Hanley et al., 2016); (2) levels of ANS have been following cyclical patterns in many countries. This is observed for the countries shown in Figure 1. It is clear from the trends that countries which started with higher levels of ANS at the time of wave 2 (the initial wave in our models) faced a decline over the following decade before starting to rise again.

Keeping these facts in mind, it is likely that governments of the countries which spend more on the welfare of people in the short-run, have lower national savings rates and have lower initial ANS (Ma & Yi, 2010, Parker, 1999, Schor, 1999, Yang & Jianfeng, 2007). Over short time horizons, these countries may achieve higher life-satisfaction of their citizens as they boost near-term welfare at the expense of building longer-term capital. Over the longer time horizons (i.e., our group 3 with its 20 years' time period), countries that have low initial ANS may subsequently have to cut back on welfare related expenditure in order to rebuild their capital, and this results in lower long-term SWB. This is consistent with the direction of our results across all four groups. In two of our six cases, our group 3 (20 year) results are significantly positive, consistent with the relationship expected from theory. Our other group 3 (longer time horizon) coefficients, while positive, are not significantly different from zero which may reflect the still short time horizon in our data relative to that needed to truly capture the positive well-being impacts of higher ANS over the very long-run.

Figure 1: Trends of ANS excluding PM as % GNI of countries included in the analysis



Source: Plotted from the ANS data downloaded from World Bank's WDI database.

Table 6: Group 1 (Wave 2 and 4)

	Dependent variable: SWB	
	OLS	
	ANS INC PM	ANS EXC PM
	(1)	(2)
age	-0.08*** (0.01)	-0.08*** (0.01)
age_squared	0.001*** (0.0001)	0.001*** (0.0001)
age_na	-1.94*** (0.43)	-1.92*** (0.43)
sex_Female	0.12*** (0.04)	0.12*** (0.04)
ms_Divorced	-0.63*** (0.11)	-0.64*** (0.11)
ms_Single	-0.57*** (0.10)	-0.57*** (0.10)
ms_Widowed	-0.30*** (0.06)	-0.31*** (0.06)
ms_Missing	-0.17 (0.47)	-0.17 (0.47)
es_Unemployed	0.004 (0.09)	-0.0001 (0.09)
es_Housewife	0.24*** (0.06)	0.24*** (0.06)
es_Student	-0.27*** (0.06)	-0.26*** (0.06)
es_Retired	-0.69*** (0.07)	-0.69*** (0.07)
es_Other	-0.36** (0.15)	-0.36** (0.15)
es_Missing	-0.09 (0.19)	-0.09 (0.19)
in_second step	0.07 (0.09)	0.07 (0.09)
in_Third step	0.26*** (0.09)	0.26*** (0.09)
in_Fourth step	0.72*** (0.09)	0.72*** (0.09)
in_Fifth step	1.01*** (0.09)	1.01*** (0.09)
in_Sixth step	1.28*** (0.10)	1.28*** (0.10)
in_Seventh step	1.49*** (0.10)	1.48*** (0.10)
in_Eigth step	1.75*** (0.10)	1.74*** (0.10)
in_Nineth step	1.75*** (0.12)	1.75*** (0.12)
in_Tenth step	1.84*** (0.13)	1.84*** (0.13)
in_Missing	1.20*** (0.10)	1.20*** (0.10)
ed_Primary	0.36*** (0.08)	0.35*** (0.08)
ed_Secondary	0.32*** (0.08)	0.31*** (0.08)
ed_University	0.32*** (0.09)	0.32*** (0.09)
ed_Missing	0.52*** (0.17)	0.51*** (0.17)
swb_t0	0.47*** (0.04)	0.45*** (0.04)
ANS_inc_pm	-0.03*** (0.002)	
ANS_exc_pm		-0.04*** (0.002)
Unemp	-0.04*** (0.003)	-0.04*** (0.003)
Inflation_rate	0.0004 (0.0005)	0.0003 (0.0005)
log(GNI_PPP)	0.59*** (0.03)	0.56*** (0.03)
Constant	-0.68* (0.42)	-0.23 (0.42)
Observations	17,733	17,733
R^2	0.14	0.14
Adjusted R^2	0.14	0.14
Residual Std. Error	2.37	2.37
F Statistic	86.89***	87.26***
Note:		*p**p***p<0.01

Each of the macro variables (SWB, ANS, Umemployment, inflation rate, log (GNI-PPP) are as at the initial wave.)

Table 7: Group 2 (Wave 2 and 5)

	Dependent variable: SWB	
	OLS	
	ANS INC PM	ANS EXC PM
	(1)	(2)
age	-0.04*** (0.01)	-0.04*** (0.01)
age_squared	0.0004*** (0.0001)	0.0004*** (0.0001)
age_na	-2.61*** (0.94)	-2.57*** (0.95)
sex_Female	0.12*** (0.04)	0.12*** (0.04)
sex_Missing	-0.90 (1.35)	-0.87 (1.36)
ms_Divorced	-0.45*** (0.08)	-0.46*** (0.08)
ms_Single	-0.44*** (0.09)	-0.45*** (0.09)
ms_Widowed	-0.22*** (0.05)	-0.22*** (0.05)
ms_Missing	0.21 (0.31)	0.22 (0.31)
es_Unemployed	0.04 (0.08)	0.04 (0.07)
es_Housewife	0.07 (0.06)	0.05 (0.06)
es_Student	-0.38*** (0.06)	-0.37*** (0.06)
es_Retired	-0.53*** (0.07)	-0.52*** (0.07)
es_Other	-0.68*** (0.12)	-0.66*** (0.12)
es_Missing	-0.48*** (0.11)	-0.46*** (0.11)
in_second step	0.21** (0.09)	0.22** (0.09)
in_Third step	0.33*** (0.08)	0.33*** (0.08)
in_Fourth step	0.54*** (0.08)	0.55*** (0.08)
in_Fifth step	0.80*** (0.08)	0.81*** (0.08)
in_Sixth step	1.04*** (0.08)	1.05*** (0.08)
in_Seventh step	1.29*** (0.09)	1.30*** (0.09)
in_Eigth step	1.35*** (0.09)	1.36*** (0.09)
in_Nineth step	1.36*** (0.14)	1.35*** (0.14)
in_Tenth step	1.24*** (0.14)	1.21*** (0.14)
in_Missing	0.73*** (0.08)	0.69*** (0.08)
ed_Primary	0.37*** (0.08)	0.37*** (0.08)
ed_Secondary	0.47*** (0.08)	0.46*** (0.08)
ed_University	0.34*** (0.08)	0.34*** (0.08)
ed_Missing	0.01 (0.25)	0.02 (0.25)
swb_t0	-0.32*** (0.04)	-0.37*** (0.05)
ANS_inc_pm	-0.04*** (0.004)	
ANS_exc_pm		-0.05*** (0.004)
Unemp	-0.03*** (0.004)	-0.04*** (0.004)
Inflation_rate	0.001*** (0.0001)	0.001*** (0.0001)
log(GNI_PPP)	0.40*** (0.02)	0.37*** (0.02)
Constant	6.54*** (0.34)	7.39*** (0.36)
Observations	16,831	16,831
R^2	0.11	0.12
Adjusted R^2	0.11	0.11
Residual Std. Error	2.11	2.11
F Statistic	63.99***	65.27***

See note to Table 5

Table 8: Group 3 (Wave 2 and 6)

	Dependent variable: SWB	
	OLS	
	ANS INC PM	ANS EXC PM
	(1)	(2)
age	-0.02*** (0.01)	-0.02*** (0.01)
age_squared	0.0002*** (0.0001)	0.0002*** (0.0001)
age_na	0.65 (0.41)	0.64 (0.41)
sex_Female	0.01 (0.03)	0.01 (0.03)
sex_Missing	-0.44 (0.84)	-0.45 (0.84)
ms_Divorced	-0.28*** (0.08)	-0.28*** (0.08)
ms_Single	-0.27*** (0.08)	-0.27*** (0.08)
ms_Widowed	-0.20*** (0.04)	-0.20*** (0.04)
ms_Missing	-1.10*** (0.39)	-1.10*** (0.39)
es_Unemployed	-0.03 (0.07)	-0.03 (0.07)
es_Housewife	0.04 (0.05)	0.04 (0.05)
es_Student	0.002 (0.06)	0.001 (0.06)
es_Retired	-0.33*** (0.05)	-0.33*** (0.05)
es_Other	-0.29*** (0.09)	-0.29*** (0.09)
es_Missing	-0.25*** (0.06)	-0.26*** (0.06)
in_second step	0.002 (0.09)	0.002 (0.09)
in_Third step	-0.16** (0.08)	-0.16** (0.08)
in_Fourth step	0.03 (0.08)	0.03 (0.08)
in_Fifth step	0.26*** (0.08)	0.26*** (0.08)
in_Sixth step	0.51*** (0.08)	0.51*** (0.08)
in_Seventh step	0.84*** (0.08)	0.84*** (0.08)
in_Eigth step	1.27*** (0.09)	1.27*** (0.09)
in_Nineth step	1.64*** (0.11)	1.64*** (0.11)
in_Tenth step	2.12*** (0.15)	2.12*** (0.15)
in_Missing	0.54*** (0.10)	0.54*** (0.10)
ed_Primary	0.35*** (0.07)	0.36*** (0.07)
ed_Secondary	0.45*** (0.07)	0.45*** (0.07)
ed_University	0.38*** (0.08)	0.38*** (0.08)
ed_Missing	0.59* (0.34)	0.59* (0.34)
swb_t0	0.21*** (0.04)	0.22*** (0.04)
ANS_inc_pm	0.01*** (0.002)	
ANS_exc_pm		0.01*** (0.002)
Unemp	-0.04*** (0.003)	-0.04*** (0.003)
Inflation_rate	0.002*** (0.0001)	0.002*** (0.0001)
log(GNI_PPP)	0.43*** (0.02)	0.43*** (0.02)
Constant	1.96*** (0.37)	1.88*** (0.38)
Observations	21,035	21,035
R^2	0.11	0.11
Adjusted R^2	0.10	0.10
Residual Std. Error	2.08	2.09
F Statistic	72.69***	72.66***

See note to Table 5

Table 9: Group 4 (Wave 4 and 6)

	Dependent variable: SWB	
	OLS	
	ANS INC PM	ANS EXC PM
	(1)	(2)
age	-0.03*** (0.005)	-0.03*** (0.005)
age_squared	0.0004*** (0.0000)	0.0004*** (0.0000)
age_na	-0.16 (0.26)	-0.16 (0.26)
sex_Female	-0.02 (0.02)	-0.02 (0.02)
sex_Missing	-0.17 (0.85)	-0.17 (0.85)
ms_Divorced	-0.39*** (0.06)	-0.39*** (0.06)
ms_Single	-0.34*** (0.06)	-0.34*** (0.06)
ms_Widowed	-0.25*** (0.03)	-0.25*** (0.03)
ms_Missing	-0.23 (0.21)	-0.23 (0.21)
es_Unemployed	-0.04 (0.05)	-0.04 (0.05)
es_Housewife	0.10*** (0.04)	0.10*** (0.04)
es_Student	0.08 (0.05)	0.08 (0.05)
es_Retired	-0.22*** (0.05)	-0.22*** (0.05)
es_Other	-0.07 (0.07)	-0.07 (0.07)
es_Missing	0.33*** (0.05)	0.34*** (0.05)
in_second step	0.04 (0.07)	0.04 (0.07)
in_Third step	-0.01 (0.06)	-0.01 (0.06)
in_Fourth step	0.29*** (0.06)	0.29*** (0.06)
in_Fifth step	0.53*** (0.06)	0.53*** (0.06)
in_Sixth step	0.75*** (0.06)	0.75*** (0.06)
in_Seventh step	1.06*** (0.06)	1.06*** (0.06)
in_Eigth step	1.40*** (0.07)	1.40*** (0.07)
in_Nineth step	1.75*** (0.09)	1.76*** (0.09)
in_Tenth step	2.15*** (0.11)	2.15*** (0.11)
in_Missing	0.76*** (0.08)	0.76*** (0.08)
ed_Primary	0.39*** (0.05)	0.39*** (0.05)
ed_Secondary	0.47*** (0.05)	0.47*** (0.05)
ed_University	0.50*** (0.05)	0.50*** (0.05)
ed_Missing	0.54*** (0.18)	0.54*** (0.18)
swb_t0	0.41*** (0.02)	0.41*** (0.02)
ANS_inc_pm	-0.01*** (0.002)	
ANS_exc_pm		-0.005*** (0.002)
Unemp	-0.02*** (0.002)	-0.02*** (0.002)
Inflation_rate	0.01*** (0.001)	0.01*** (0.001)
log(GNI_PPP)	-0.01 (0.01)	-0.02 (0.01)
Constant	4.32*** (0.16)	4.35*** (0.16)
Observations	36,316	36,316
R^2	0.11	0.11
Adjusted R^2	0.10	0.10
Residual Std. Error	2.11	2.11
F Statistic	125.95***	125.89***

See note to Table 5

Table 10: Group 1 (Wave 2 and 4)

	Dependent variable: ΔSWB per year	
	OLS	
	ANS INC PM	ANS EXC PM
	(1)	(2)
gr_15-29 male	0.01 (0.03)	0.01 (0.03)
gr_30-44 female	-0.02 (0.03)	-0.02 (0.03)
gr_30-44 male	0.001 (0.04)	0.0005 (0.04)
gr_45-59 female	-0.01 (0.03)	-0.01 (0.03)
gr_45-59 male	-0.02 (0.03)	-0.02 (0.03)
gr_60+ female	0.02 (0.03)	0.02 (0.03)
gr_60+ male	0.04 (0.04)	0.04 (0.04)
swb_t0	-0.05^{***} (0.01)	-0.05^{***} (0.01)
ANS_inc_pm	-0.005^{***} (0.001)	
ANS_exc_pm		-0.01^{***} (0.001)
Unemp	-0.01^{***} (0.001)	-0.01^{***} (0.001)
Inflation_rate	-0.0000 (0.0002)	-0.0000 (0.0002)
log(GNI_PPP)	0.06^{***} (0.01)	0.06^{***} (0.01)
Constant	-0.17 (0.15)	-0.12 (0.15)
Observations	80	80
R^2	0.55	0.57
Adjusted R^2	0.47	0.49
Residual Std. Error	0.07	0.07
F Statistic	6.88^{***}	7.38^{***}

See note to Table 5

Table 11: Group 3 (Wave 2 and 6)

	Dependent variable: ΔSWB per year	
	OLS	
	ANS INC PM	ANS EXC PM
	(1)	(2)
gr_15-29 male	0.01 (0.01)	0.01 (0.01)
gr_30-44 female	-0.01 (0.01)	-0.01 (0.01)
gr_30-44 male	0.003 (0.01)	0.003 (0.01)
gr_45-59 female	-0.01 (0.01)	-0.01 (0.01)
gr_45-59 male	-0.01 (0.01)	-0.01 (0.01)
gr_60+ female	-0.02 (0.02)	-0.02 (0.02)
gr_60+ male	-0.01 (0.01)	-0.01 (0.01)
swb_t0	-0.03^{***} (0.004)	-0.03^{***} (0.004)
ANS_inc_pm	0.0003 (0.001)	
ANS_exc_pm		0.0003 (0.001)
Unemp	-0.001^{*} (0.001)	-0.001^{*} (0.001)
Inflation_rate	0.0001^{***} (0.0000)	0.0001^{***} (0.0000)
log(GNI_PPP)	0.02^{***} (0.005)	0.02^{***} (0.005)
Constant	0.06 (0.05)	0.06 (0.05)
Observations	86	86
R^2	0.47	0.47
Adjusted R^2	0.38	0.38
Residual Std. Error	0.03	0.03
F Statistic	5.36^{***}	5.37^{***}

See note to Table 5

Table 12: Group 2 (Wave 2 and 5)

	Dependent variable: ΔSWB per year	
	OLS	
	ANS INC PM	ANS EXC PM
	(1)	(2)
gr_15-29 male	-0.003 (0.01)	-0.003 (0.01)
gr_30-44 female	-0.01 (0.01)	-0.01 (0.01)
gr_30-44 male	-0.005 (0.01)	-0.005 (0.01)
gr_45-59 female	-0.03 (0.02)	-0.03 (0.02)
gr_45-59 male	-0.02 (0.02)	-0.02 (0.02)
gr_60+ female	-0.02 (0.02)	-0.02 (0.02)
gr_60+ male	-0.03 (0.02)	-0.03 (0.02)
swb_t0	-0.05^{***} (0.01)	-0.05^{***} (0.01)
ANS_inc_pm	-0.001 (0.001)	
ANS_exc_pm		-0.001^{*} (0.001)
Unemp	-0.001 (0.001)	-0.001 (0.001)
Inflation_rate	0.0001^{***} (0.0000)	0.0001^{***} (0.0000)
log(GNI_PPP)	0.03^{***} (0.01)	0.03^{***} (0.005)
Constant	0.13^{**} (0.06)	0.15^{***} (0.06)
Observations	86	86
R^2	0.62	0.63
Adjusted R^2	0.56	0.57
Residual Std. Error	0.04	0.04
F Statistic	10.12^{***}	10.32^{***}

See note to Table 5

Table 13: Group 4 (Wave 4 and 6)

	Dependent variable: ΔSWB per year	
	OLS	
	ANS INC PM	ANS EXC PM
	(1)	(2)
gr_15-29 male	0.01 (0.02)	0.01 (0.02)
gr_30-44 female	-0.01 (0.02)	-0.01 (0.02)
gr_30-44 male	-0.002 (0.02)	-0.002 (0.02)
gr_45-59 female	-0.02 (0.02)	-0.02 (0.02)
gr_45-59 male	-0.01 (0.02)	-0.01 (0.02)
gr_60+ female	-0.03 (0.02)	-0.03 (0.02)
gr_60+ male	-0.02 (0.02)	-0.02 (0.02)
swb_t0	-0.06^{***} (0.01)	-0.06^{***} (0.01)
ANS_inc_pm	-0.001 (0.001)	
ANS_exc_pm		-0.001 (0.001)
Unemp	-0.001 (0.001)	-0.001 (0.001)
Inflation_rate	0.001^{***} (0.0003)	0.001^{***} (0.0003)
log(GNI_PPP)	0.01 (0.01)	0.01 (0.01)
Constant	0.38^{***} (0.06)	0.39^{***} (0.06)
Observations	168	168
R^2	0.44	0.44
Adjusted R^2	0.40	0.40
Residual Std. Error	0.07	0.07
F Statistic	10.31^{***}	10.29^{***}

See note to Table 5

7.6 Conclusion

ANS (or GS, CI, CW) has been widely applied as a comprehensive measure of weak-sustainability. As such it has been used as a tool to predict aggregate objective well-being (Ferreira, Hamilton, & Vincent, 2008, Gnègnè, 2009, Greasley et al., 2014, 2016, Hanley et al., 2016). In this paper, we have focused on adopting ANS to model future individual level SWB and aggregate group changes in SWB. To the best of our knowledge, this study is the first attempt in this regard that includes controls for initial levels of SWB of a country.

We used the data for self-reported life-satisfaction and other personal traits such as age, sex, marital status, income level, and education provided by WVS in waves 2, 4, 5 and 6. This data was gathered in four groups of countries in which each country is surveyed in two different waves (i.e. four groups of countries being those surveyed in: wave 2 and 4, wave 2 and 5, wave 2 and 6, and wave 4 and 6). Individual level data was combined with macroeconomic data from the World Bank and other sources.

The key relationships that we find are as follows. Firstly, over horizons of 10 – 15 years, the level of SWB in a given period is negatively associated with ANS in the initial period at individual level, and for 9 of 12 specifications this relationship is significantly different from zero. Secondly, for a 20-year time horizon this relationship turns positive (significantly so in our OLS model 2 specifications). These results are consistent with political economy dynamics in which a country that starts off with lower ANS tends to spend more on the current welfare of people at the expense of its savings. This raises individuals' life-satisfaction in the short-term but diminishes the reserves available to raise people's well-being over longer time horizons. This shift is captured by the switch to a positive relationship over the 20-year time horizon. These results hold for both individual level and aggregate group level results. It is important to note that ANS is regarded as a sustainability measure for infinite time horizons and 20 years is still a relatively short time period to study this hypothesised long-term relationship. Lack of longer term data mean that we cannot assess the relationship over even longer time horizons. We leave this to be examined in future research as more data becomes available.

Overall, our results highlight an important political economy challenge for policies that are designed to boost sustainable outcomes (proxied, in our case, by higher ANS). Governments that act in this way may suffer in the short term (that is relevant to political cycles) relative to more profligate governments, and so potentially lose political power. This political economy challenge may help to explain why many governments do not run sustainable policies. Our 20-year time horizon results indicate that it would be beneficial to examine the relationship between ANS and SWB over longer-time horizons. Such an analysis – as data becomes available for future survey waves – would contribute to a better understanding of whether people gain intergenerationally in terms of both sustainability and well-being when governments are focused on maintaining or increasing ANS as posited by the broader literature on genuine savings and related measures.

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Appendix

A1. Calculation of adjusted net savings

ANS is calculated as:

$$ANS = (\,GNS - D_h + CSE - \sum R_{n,i} \, - CD \, - PM) \,/\, GNI$$

Where:

ANS Adjusted net savings

GNS Gross national savings

D_h Depreciation of fixed capital

CSE Current (non-fixed capital) i.e. expenditure on education

$R_{n,i}$ Rent from the depletion of natural capital

CD Damages from carbon dioxide emissions

PM Damages from particulate matter (included in PM adjusted ANS only)

GNI Gross national income at market prices

Gross national savings (GNS):

According to the World Bank methodology, GNS is calculated as the difference between GNI and public and private consumption plus net transfers.

Depreciation of fixed capital:

It is the replacement value of capital consumed in the process of production. It is estimated as a share of national consumption of fixed capital.

Expenditure on education:

Education expenditure is used to proxy human capital investments in ANS equation. It includes current operating expenditure on education at all levels i.e. primary, secondary, tertiary, vocational etc. which include salaries and wages and excludes capital expenditures such as spending on buildings and equipment.

Rent from natural resources:

Rents from the extraction of minerals and energy resources e.g. crude oil, gas, coal etc. is given by:

$$Rent = \; Production\ volume \; \times (\,Market\ price - Cost\ of\ production\,)$$

Damages from carbon dioxide:

The World Bank assumes a conservative figure of $20 as the global marginal social cost of a metric ton of CO_2 emission from Fankhauser (1994).

Damages from particulate matter:

PM damages estimates are given by the willingness to pay for the prevention of morbidity and mortality attributed to particulate matter emissions. It is included only in the PM adjusted estimates of ANS.

A2. Data appendix

A2.1. SWB and personal controls

Q: SWB				
Survey Question	**Response values**	**Question #**	**Notes**	**Data processing**
All things considered, how satisfied are you with your life as a whole these days? Using this card on which 1 means you are “completely dissatisfied” and 10 means you are “completely satisfied” where would you put your satisfaction with your life as a whole? (Code one number): Completely dissatisfied Completely satisfied 1 2 3 4 5 6 7 8 9 10	-5 Missing; Not asked by the interviewer -4 Not asked -3 Not applicable -2 No answer -1 Don´t know 1 Dissatisfied 2 3 4 5 6 7 8 9 10 Satisfied	Wave 2: V96 Wave 4: V81 Wave 5: V22 Wave 6: V23	This variable and its responses are consistent across all surveys **Unique values in the data** -5, -2, -1, 1,2,3,4,5,6,7,8,9,10	Dropped rows with missing values i.e.: -5, -2, -1 **Remaining unique values** 1,2,3,4,5,6,7,8,9,10
Q: Age				
Can you tell me your year of birth, please? 19____ (write in last two digits) This means you are ____ years old (write in age in two digits).	-5 Missing; Unknown -4 Not asked in survey -3 Not applicable -2 No answer -1 Don´t know	Wave 2: V355 Wave 4: V225 Wave 5: V237 Wave 6: V242	This variable and its responses are consistent across all surveys **Unique values in the data** -5, -3, -2, -1, 15 – 99	Re-coded missing values as -5 i.e. -5, -3, -2, -1 replaced with -5 **Remaining unique values** Non-missing: 15 – 99 Missing: -5 **Age missing dummy** 1 for -5 and 0 otherwise
Q: Sex				
Sex of respondent: 1 Male 2 Female	-5 Missing; Unknown -4 Not asked in survey -3 Not applicable -2 No answer -1 Don´t know 1 Male 2 Female 9 na (only two rows in wave 4)	Wave 2: V353 Wave 4: V223 Wave 5: V235 Wave 6: V240	This variable and its responses are consistent across all surveys **Unique values in the data** -5, -2, 1,2,9	Re-coded missing values as 99 i.e. -5, -2, 9 replaced with 99 **Sex dummies** Male Female Missing
Q: Marital status				
Are you currently (read out and code one answer only): 1 Married 2 Living together as married 3 Divorced	-5 Missing -4 Not asked in survey -3 Not applicable -2 No answer	Wave 2: V181 Wave 4: V106 Wave 5: V55 Wave 6: V57	This variable and its responses are consistent across all surveys **Unique values in the data** -5, -2, -1, 1,2,3,4,5,6,10	**Variable re-coding** 1. Married: 1,2,10 2. Divorced: 3,4 3. Single: 5 4. Widowed: 6

4 Separated 5 Widowed 6 Single	-1 Don´t know 1 Married 2 Living together as married 3 Divorced 4 Separated 5 Widowed 6 Single 10 Living apart while married/cohabitation			99 Missing: -5, -2, -1
Q: Employment				
Are you employed now or not?	-5 Missing; RU: Inappropriate response -4 Not asked -3 Not applicable -2 No answer;SG: Refused -1 Don´t know 1 Full-time 2 Part-time 3 Self-employed 4 Retired 5 Housewife 6 Students 7 Unemployed 8 Other	Wave 2: V358 Wave 4: V229 Wave 5: V241 Wave 6: V229	This variable and its responses are consistent across all surveys **Unique values in the data** -5, -4, -3, -2, -1, 1,2,3,4,5,6,7,8	**Variable re-coding** 1. Employed: 1,2,3 2. Unemployed: 4 3. Housewife: 5 4. Student: 6 5. Retired: 7 6. Other: 8 99 Missing: -5, -4, -3, -2, -1
Q: Income scale				
On this card is an income scale on which 1 indicates the lowest income group and 10 the highest income group in your country. We would like to know in what group your household is. Please, specify the appropriate number, counting all wages, salaries, pensions and other incomes that come in. (Code one number): Lowest group Highest group 1 2 3 4 5 6 7 8 9 10	-5 Missing; Not asked by the interviewer -4 Not asked -3 Not applicable -2 No answer -1 Don´t know 1 Lower step 2 second step 3 Third step 4 Fourth step 5 Fifth step 6 Sixth step 7 Seventh step 8 Eigth step 9 Nineth step 10 Upper step	Wave 2: V363 Wave 4: V236 Wave 5: V253 Wave 6: V239	This variable and its responses are consistent across all surveys **Unique values in the data** -5, -4, -2, -1, 1,2,3,4,5,6,7,8,9,10	**Variable re-coding** 1 – 10 steps of income 99 Missing: -5, -4, -2, -1
Q: Education				
What is the highest educational level that you have attained? [NOTE: if respondent indicates to be a student, code highest level s/he expects to complete]:	-5 Missing; Not asked by the interviewer -4 Not asked -3 Not applicable -2 No answer	Wave 2: V375 Wave 4: V226 Wave 5: V238 Wave 6: V248	This variable and its responses are consistent across all surveys **Unique values in the data**	**Variable re-coding** 1. No education: 1 2. Primary: 2,3 3. Secondary: 4,5,6,7

1 No formal education 2 Incomplete primary school 3 Complete primary school 4 Incomplete secondary school: technical/vocational type 5 Complete secondary school: technical/vocational type 6 Incomplete secondary: university-preparatory type 7 Complete secondary: university-preparatory type 8 Some university-level education, without degree 9 University-level education, with degree	-1 Don´t know 1 No formal education 2 Incomplete primary school 3 Complete primary school 4 Incomplete secondary school: technical/ vocational type 5 Complete secondary school: technical/ vocational type 6 Incomplete secondary school: university-preparatory type 7 Complete secondary school: university-preparatory type 8 Some university-level education, without degree 9 University - level education, with degree		-5, -4, -3, -2, -1, 1,2,3,4,5,6,7,8,9	4. University: 8,9 99. issing: -5, -4, -3, -2, -1

A2.2. Adjusted Net Savings and macro controls

Variable		**Definition**	**Note and data processing**
ANS_exc_pm	Adjusted net savings, excluding particulate emission damage (% of GNI)	Adjusted net savings are equal to net national savings plus education expenditure and minus energy depletion, mineral depletion, net forest depletion, and carbon dioxide. This series excludes particulate emissions damage. Where Net National Saving (NNS), is calculated as the difference between gross national savings and depreciation/consumption of fixed capital; and gross national savings (GNS) are calculated as the difference between gross national income and public and private consumption plus net current transfers according to the World Bank methodology (Bolt, Matete, & Clemens, 2002).	Any country which does not have ANS data for the year it was surveyed (or immediate previous or following year) for WVS was dropped from the final dataset.
ANS_inc_pm	Adjusted net savings, including particulate emission damage (% of GNI)	Adjusted net savings are equal to net national savings plus education expenditure and minus energy depletion, mineral depletion, net forest depletion, and carbon dioxide and particulate emissions damage. (where net national savings is as defined above)	Same as above
Unemployment	Unemployment, total (% of total labor force) (modeled ILO estimate)	Unemployment refers to the share of the labor force that is without work but available for and seeking employment.	This data series starts from 1991 for all countries in WDI data from the World Bank. We used 1991 unemployment figures for the countries which were survey in 1990.
CPI	Inflation, consumer prices (annual %)	Inflation as measured by the consumer price index reflects the annual percentage change in the cost to the average consumer of acquiring a basket of goods and services that may be fixed or	

		changed at specified intervals, such as yearly. The Laspeyres formula is generally used.	
GNI_PPP	GNI per capita, PPP (constant 2011 international $)	GNI per capita based on purchasing power parity (PPP). PPP GNI is gross national income (GNI) converted to international dollars using purchasing power parity rates. An international dollar has the same purchasing power over GNI as a U.S. dollar has in the United States. GNI is the sum of value added by all resident producers plus any product taxes (less subsidies) not included in the valuation of output plus net receipts of primary income (compensation of employees and property income) from abroad. Data are in constant 2011 international dollars.	**Data for China was downloaded from:** http://hdr.undp.org/en/data China GNI data has the same base year

Data sources:

1. **SWB and personal controls**

   Data is downloaded from World Values Survey website accessed on Monday, 12June 2017. URLs for each wave as :following

   Wave 2: http://www.worldvaluessurvey.org/WVSDocumentationWV2.jsp

   Wave 4: http://www.worldvaluessurvey.org/WVSDocumentationWV4.jsp

   Wave 5: http://www.worldvaluessurvey.org/WVSDocumentationWV5.jsp

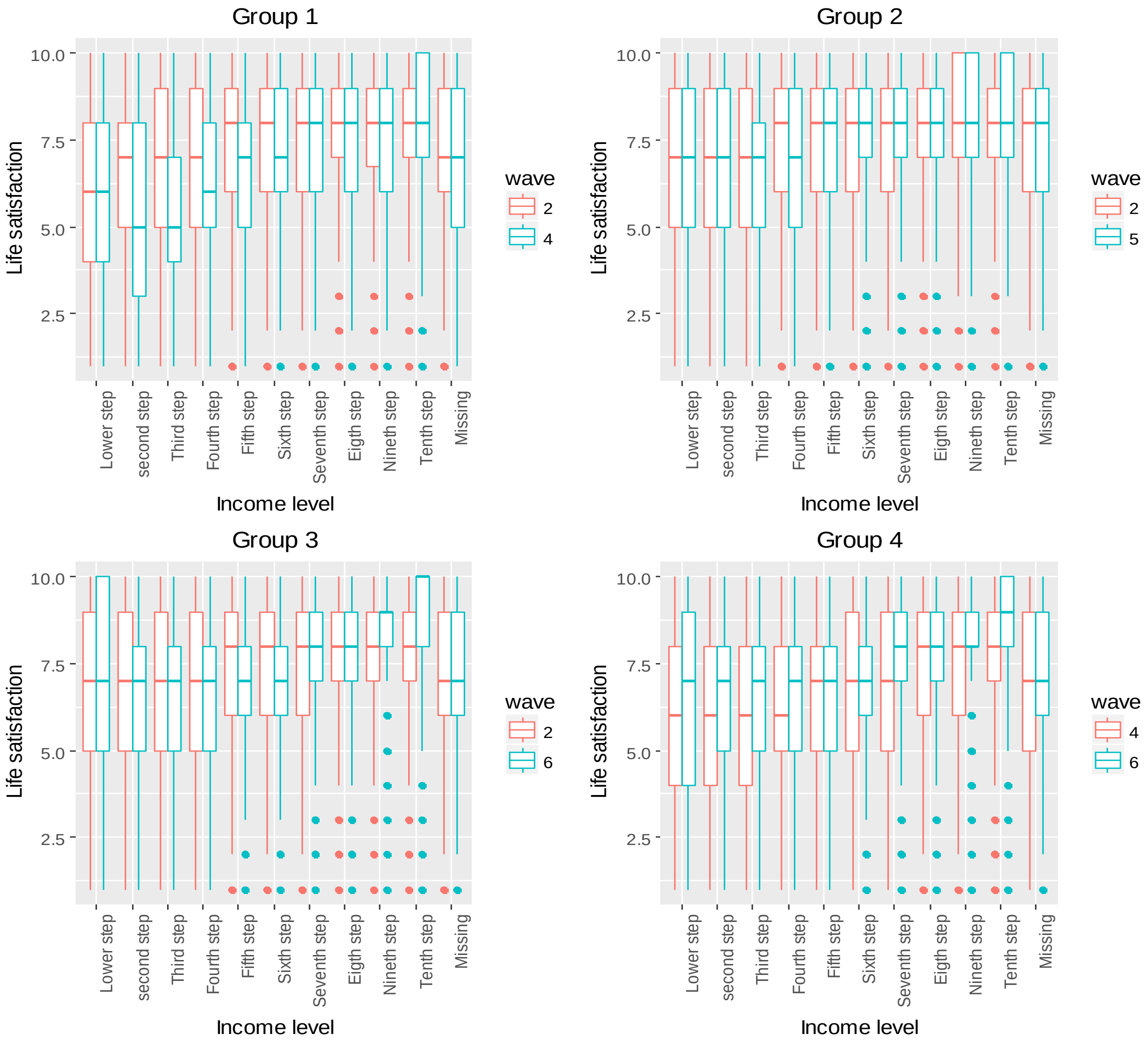
   Wave 6: http://www.worldvaluessurvey.org/WVSDocumentationWV6.jsp

2. **Adjusted Net Savings and macro controls**

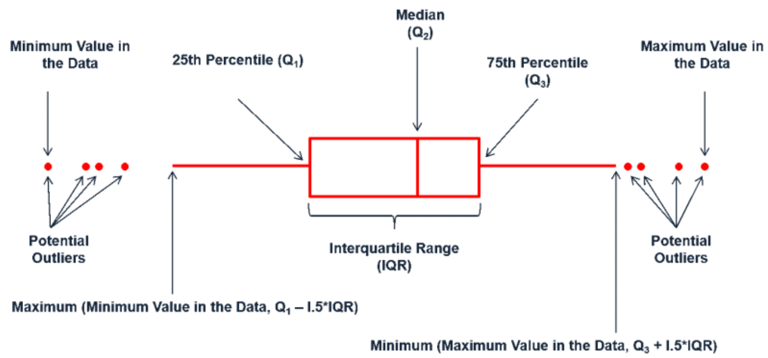
   Adjusted net savings (ANS) and macro controls data is downloaded from the following links:

   1. http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators
   2. GNI-PPP data for China downloaded from http://hdr.undp.org/en/data

Figure A2.1. Distribution of SWB by income level in each group

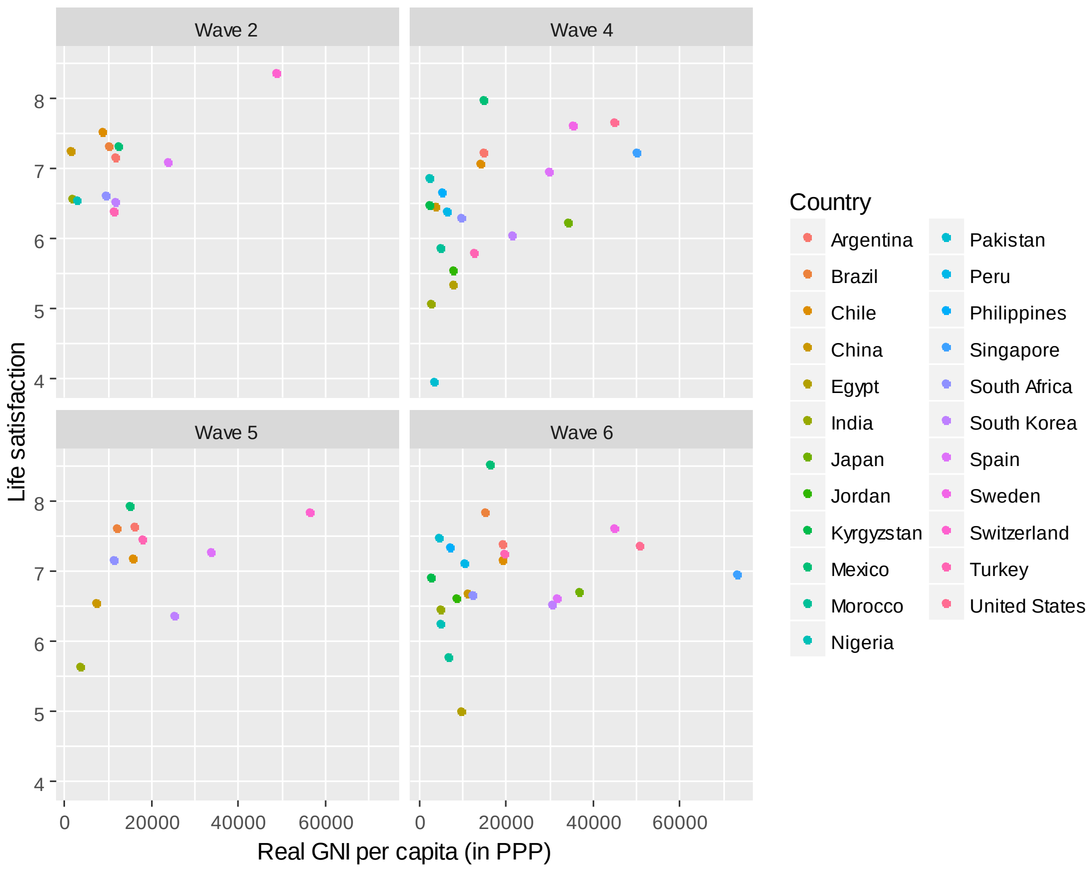


NOTE: This box plot represents the relationship between life-satisfaction and income levels by data groups and by wave within each group. A boxplot summarises minimum, 1st quartile, median, 3rd quartile and maximum values of life-satisfaction for each income step. Some outliers on the lower end of life-satisfaction in certain income steps are represented by dots. Following diagram illustrates how to read a boxplot.



Source: https://www.leansigmacorporation.com/wp/wp-content/uploads/2015/12/Box-Plot-MTB_01.png

Figure A2.2. Distribution of SWB by real (ppp-adjusted) GNI per capita



A2.3. Adjusted Net Savings and macro controls dataset

Country Name	**Year**	**wave**	**ANS_exc_pm (% of GNI)**	**ANS_inc_pm (% of GNI)**	**Unemployment (% of total labor force)**	**CPI (annual %)**	**GNI-PPP (constant 2011 international $)**
Argentina	1991	w2	7.3	7.0	5.8	171.7	11,676
Argentina	1999	w4	6.1	5.9	14.1	-1.2	14,815
Argentina	2006	w5	10.2	10.1	9.4	10.9	16,077
Argentina	2013	w6	7.9	7.7	7.1	10.6	19,077
Brazil	1991	w2	14.1	13.4	10.2	432.8	10,103
Brazil	2006	w5	10.7	10.5	11.5	4.2	12,140
Brazil	2014	w6	10.5	10.3	6.8	6.3	15,077
Chile	1990	w2	5.6	5.3	5.3	26.0	8,579
Chile	2000	w4	5.9	5.7	9.2	3.8	13,905
Chile	2006	w5	2.4	2.3	7.7	3.4	15,650
Chile	2011	w6	4.2	4.1	7.1	3.3	19,187
China	1990	w2	19.2	17.9	4.9	3.1	1,487
China	2001	w4	20.2	19.5	4.5	0.7	3,883
China	2007	w5	28.5	28.0	3.8	4.8	7,258
China	2012	w6	23.2	22.7	4.5	2.6	10,981
Egypt	2001	w4	12.0	11.3	9.3	2.3	7,592
Egypt	2013	w6	4.5	3.9	13.2	9.4	9,778
India	1990	w2	13.8	10.7	4.0	9.0	1,732
India	2001	w4	15.7	13.8	3.8	3.7	2,548
India	2006	w5	23.5	22.2	4.3	6.1	3,393
India	2012	w6	21.8	20.5	3.6	9.3	4,771
Japan	2000	w4	12.4	12.2	4.7	-0.7	34,382
Japan	2010	w6	6.2	6.1	5.1	-0.7	36,685
Jordan	2001	w4	11.1	10.9	15.8	1.8	7,603
Jordan	2014	w6	14.0	13.9	11.9	2.9	8,525
Kyrgyzstan	2003	w4	-4.0	-5.0	9.9	3.0	2,166
Kyrgyzstan	2011	w6	3.3	2.6	8.5	16.5	2,610
Mexico	1990	w2	8.8	8.2	3.0	26.7	12,178
Mexico	2000	w4	11.6	11.4	2.6	9.5	14,696
Mexico	2005	w5	10.6	10.4	3.6	4.0	15,002
Mexico	2012	w6	11.0	10.8	4.9	4.1	16,293
Morocco	2001	w4	26.6	26.3	12.5	0.6	4,665
Morocco	2011	w6	22.0	21.7	8.9	0.9	6,576
Nigeria	1990	w2	-11.7	-13.7	5.9	7.4	2,753
Nigeria	2000	w4	5.3	3.3	6.7	6.9	2,388
Nigeria	2011	w6	8.0	6.6	7.3	10.8	4,970
Pakistan	2001	w4	12.0	9.3	7.8	3.1	3,442
Pakistan	2012	w6	12.1	10.4	6.0	9.7	4,589
Peru	2001	w4	7.1	6.7	7.9	2.0	6,425
Peru	2012	w6	11.0	10.8	3.6	3.7	10,257
Philippines	2001	w4	29.4	28.7	10.9	5.3	5,043
Philippines	2012	w6	26.9	26.4	7.0	3.2	7,205
Singapore	2002	w4	25.7	25.6	5.7	-0.4	50,007
Singapore	2012	w6	38.4	38.3	2.8	4.5	73,289
South Africa	1990	w2	2.2	0.5	23.9	14.3	9,552
South Africa	2001	w4	0.9	-0.2	26.2	5.7	9,615
South Africa	2006	w5	2.0	1.3	22.6	4.6	11,323
South Africa	2013	w6	0.4	-0.0	24.6	5.8	12,125
South Korea	1990	w2	23.9	23.6	2.4	8.6	11,615
South Korea	2001	w4	16.6	16.4	4.0	4.1	21,379
South Korea	2005	w5	18.7	18.6	3.7	2.8	25,315
South Korea	2010	w6	19.5	19.4	3.7	2.9	30,387
Spain	1990	w2	12.6	12.4	15.9	6.7	23,593
Spain	2000	w4	12.0	12.0	13.8	3.4	29,853
Spain	2007	w5	10.0	10.0	8.2	2.8	33,494
Spain	2011	w6	5.3	5.2	21.4	3.2	31,511
Sweden	1999	w4	17.9	17.9	7.6	0.5	35,171
Sweden	2011	w6	18.4	18.4	7.8	3.0	44,722
Switzerland	1989	w2	17.1	18.0	1.8	3.2	48,832
Switzerland	2007	w5	18.7	18.7	3.7	0.7	56,263
Turkey	1990	w2	16.8	15.7	8.2	60.3	11,212
Turkey	2001	w4	11.1	10.5	8.4	54.4	12,518
Turkey	2007	w5	10.7	10.4	8.9	8.8	17,730
Turkey	2011	w6	9.9	9.7	8.8	6.5	19,490
United States	1999	w4	9.4	9.3	4.2	2.2	44,910
United States	2011	w6	3.7	3.6	8.9	3.2	50,705

A2.4. Summary stats WVS data

Count of individuals surveyed by country in each wave.

Data Group	Number of individuals surveyed	
Group 1	**Wave 2**	**Wave 4**
Argentina	992	1,268
Chile	1,496	1,193
China	996	991
India	2,461	1,980
Mexico	1,514	1,506
Nigeria	997	2,022
South Africa	2,696	2,995
South Korea	1,226	1,173
Spain	1,499	1,205
Turkey	1,027	3,400
Group 2	**Wave 2**	**Wave 5**
Argentina	992	995
Brazil	1,770	1,495
Chile	1,496	992
China	996	1,937
India	2,461	1,953
Mexico	1,514	1,512
South Africa	2,696	2,977
South Korea	1,226	1,197
Spain	1,499	1,195
Switzerland	1,400	1,232
Turkey	1,027	1,346
Group 3	**Wave 2**	**Wave 6**
Argentina	992	1,020
Brazil	1,770	1,483
Chile	1,496	988
China	996	2,252
India	2,461	4,054
Mexico	1,514	2,000
Nigeria	997	1,759
South Africa	2,696	3,521
South Korea	1,226	1,189
Spain	1,499	1,168
Turkey	1,027	1,601
Group 4	**Wave 4**	**Wave 6**
Argentina	1,268	1,020
Chile	1,193	988
China	991	2,252
Egypt	2,998	1,523
India	1,980	4,054
Japan	1,316	2,381
Jordan	1,216	1,200
Kyrgyzstan	1,043	1,490
Mexico	1,506	2,000
Morocco	1,251	1,173
Nigeria	2,022	1,759
Pakistan	1,693	1,200
Peru	1,490	1,206
Philippines	1,200	1,200
Singapore	1,512	1,971
South Africa	2,995	3,521
South Korea	1,173	1,189
Spain	1,205	1,168
Sweden	1,012	1,204
Turkey	3,400	1,601
United States	1,200	2,216

A2.5. Pseudo-panel data summary

Count of individuals surveyed by country and by group in each time-period (for pseudo-panel model)

Country	wave	15-29 female	15-29 male	30-44 female	30-44 male	45-59 female	45-59 male	60+ female	60+ male
Argentina	2	137	131	149	136	135	106	100	98
Argentina	4	195	197	196	156	142	133	142	107
Argentina	5	148	149	147	127	125	90	110	99
Argentina	6	136	146	156	134	123	102	126	97
Brazil	2	345	343	206	221	330	325		
Brazil	5	263	195	296	195	203	143	110	89
Brazil	6	245	147	290	147	242	148	148	116
Chile	2	276	262	250	231	143	135	116	83
Chile	4	163	165	225	193	135	119	104	89
Chile	5	141	122	180	134	124	103	100	88
Chile	6	105	125	150	129	146	136	100	97
China	2	122	179	118	183	119	175	39	59
China	4	108	85	229	210	133	158	33	35
China	5	172	126	396	289	324	313	160	157
China	6	241	215	364	371	312	311	227	211
Egypt	4	543	476	534	529	264	310	119	219
Egypt	6	298	124	365	147	233	129	137	90
India	2	400	533	488	464	150	170	101	155
India	4	242	298	323	440	174	239	111	145
India	5	183	253	338	438	202	274	111	151
India	6	404	553	682	851	450	530	234	319
Japan	4	138	107	205	168	185	161	175	177
Japan	6	147	146	312	299	339	295	431	412
Jordan	4	245	239	258	174	90	101	32	77
Jordan	6	140	208	255	175	152	116	53	101
Kyrgyzstan	4	218	174	200	174	89	74	70	43
Kyrgyzstan	6	254	238	246	222	207	197	52	74
Mexico	2	329	341	199	295	124	149	34	43
Mexico	4	275	277	280	237	137	147	69	79
Mexico	5	247	254	268	232	154	172	95	90
Mexico	6	395	388	331	304	182	193	93	114
Morocco	4	303	295	225	218	89	83	15	19
Morocco	6	240	242	188	178	99	110	59	57
Nigeria	2	230	306	128	216	23	58	19	17
Nigeria	4	532	564	364	354	81	91	13	23
Nigeria	6	522	470	239	288	83	91	27	39
Pakistan	4	287	284	420	314	93	194	17	84
Pakistan	6	229	227	264	241	68	123	17	31
Peru	4	303	298	250	235	176	151	32	45
Peru	6	198	211	199	183	128	110	76	101
Philippines	4	196	206	219	206	116	116	69	72
Philippines	6	133	149	226	171	148	176	93	104
Singapore	4	336	358	249	220	146	108	59	36
Singapore	6	284	290	315	251	255	206	210	127
South Africa	2	473	492	528	368	308	236	147	143
South Africa	4	512	557	503	502	329	249	152	190
South Africa	5	502	538	488	474	300	268	195	211
South Africa	6	621	695	648	597	348	333	144	135
South Korea	2	183	212	245	235	171	92	50	37
South Korea	4	176	133	221	223	162	188	22	48
South Korea	5	131	147	230	222	143	132	97	95
South Korea	6	119	127	197	200	158	168	127	93
Spain	2	196	216	233	189	176	104	217	168
Spain	4	131	145	166	169	129	123	193	149
Spain	5	136	138	159	180	124	125	180	153
Spain	6	117	114	179	185	128	120	174	151
Sweden	4	104	120	140	141	155	135	110	107
Sweden	6	167	137	118	123	151	121	199	188
Switzerland	2	133	122	252	221	158	125	215	173
Switzerland	5	57	44	192	132	197	163	231	216
Turkey	2	206	191	171	176	100	97	38	42
Turkey	4	609	637	659	608	307	292	121	163
Turkey	5	274	268	233	224	128	114	35	70
Turkey	6	240	269	322	274	173	163	89	71
United States	4	148	158	247	153	183	112	114	85
United States	6	198	192	246	244	347	324	352	313

A2.6. Panel model results

Results from estimating model (1) which does not deal with the endogeneity issues, are shown in this section of the appendix. Note that the coefficient on ANS changes sign in some cases, relative to Tables 6 – 9 which do account for endogeneity, demonstrating that prior studies which use current ANS and SWB are likely to have produced biased estimates.

Table 2.6.1 Group 1 (Wave 2 and 4)

	Dependent variable: SWB	
	Panel model	
	ANS INC PM	ANS EXC PM
	(1)	(2)
cr_Chile	0.01 (0.14)	0.02 (0.14)
cr_China	-3.12*** (0.27)	-3.12*** (0.27)
cr_India	-4.38*** (0.28)	-4.39*** (0.28)
cr_Mexico	0.95*** (0.22)	0.93*** (0.22)
cr_Nigeria	-3.39*** (0.26)	-3.37*** (0.26)
cr_South Africa	-2.03*** (0.24)	-2.02*** (0.24)
cr_South Korea	-0.33 (0.23)	-0.36 (0.23)
cr_Spain	0.94*** (0.14)	0.91*** (0.14)
cr_Turkey	-1.35*** (0.09)	-1.37*** (0.09)
wave4	-0.27*** (0.05)	-0.26*** (0.04)
age	-0.06*** (0.01)	-0.06*** (0.01)
age_squared	0.001*** (0.0001)	0.001*** (0.0001)
age_na	-1.28*** (0.43)	-1.28*** (0.43)
sex_Female	0.08*** (0.03)	0.08*** (0.03)
sex_Missing	-0.25* (0.15)	-0.25 (0.15)
ms_Divorced	-0.66*** (0.08)	-0.66*** (0.08)
ms_Single	-0.55*** (0.07)	-0.55*** (0.07)
ms_Widowed	-0.35*** (0.04)	-0.35*** (0.04)
ms_Missing	-0.14 (0.39)	-0.14 (0.39)
es_Unemployed	-0.08 (0.07)	-0.08 (0.07)
es_Housewife	0.21*** (0.04)	0.21*** (0.04)
es_Student	-0.10* (0.05)	-0.10** (0.05)
es_Retired	-0.68*** (0.05)	-0.68*** (0.05)
es_Other	-0.01 (0.12)	-0.02 (0.12)
es_Missing	-0.52*** (0.10)	-0.52*** (0.10)
in_second step	0.12* (0.06)	0.12* (0.06)
in_Third step	0.37*** (0.06)	0.37*** (0.06)
in_Fourth step	0.69*** (0.06)	0.69*** (0.06)
in_Fifth step	0.92*** (0.06)	0.92*** (0.06)
in_Sixth step	1.09*** (0.07)	1.08*** (0.07)
in_Seventh step	1.22*** (0.07)	1.22*** (0.07)
in_Eigth step	1.42*** (0.07)	1.41*** (0.07)
in_Nineth step	1.38*** (0.09)	1.38*** (0.09)
in_Tenth step	1.38*** (0.10)	1.38*** (0.10)
in_Missing	0.87*** (0.07)	0.87*** (0.07)
ed_Primary	0.20*** (0.07)	0.20*** (0.07)
ed_Secondary	0.41*** (0.07)	0.41*** (0.07)

ed_University	0.58*** (0.07)	0.58*** (0.07)
ed_Missing	-0.28*** (0.09)	-0.27*** (0.09)
ANS_inc_pm	0.01** (0.01)	
ANS_exc_pm		0.02*** (0.01)
Unemp	0.05** (0.02)	0.05** (0.02)
Inflation_rate	0.002* (0.001)	0.002* (0.001)
log(GNI_PPP)	-1.79*** (0.12)	-1.77*** (0.12)
Constant	24.24*** (1.14)	24.02*** (1.15)
Observations	32,637	32,637
R^2	0.13	0.13
Adjusted R^2	0.13	0.13
Residual Std. Error	2.31	2.31
F Statistic	110.57***	110.62***

See the notes to Table 5.

Table 2.6.2 Group 2 (Wave 2 and 5)

	Dependent variable: SWB	
	Panel model	
	ANS INC PM	ANS EXC PM
	(1)	(2)
cr_Brazil	0.17* (0.09)	0.20** (0.09)
cr_Chile	-0.33*** (0.07)	-0.35*** (0.07)
cr_China	-0.70*** (0.19)	-0.42** (0.20)
cr_India	-2.05*** (0.19)	-1.78*** (0.20)
cr_Mexico	0.35*** (0.08)	0.40*** (0.08)
cr_South Africa	-0.82*** (0.17)	-0.92*** (0.17)
cr_South Korea	-0.62*** (0.11)	-0.49*** (0.11)
cr_Spain	0.43*** (0.09)	0.41*** (0.09)
cr_Switzerland	1.52*** (0.12)	1.57*** (0.13)
cr_Turkey	-0.20** (0.08)	-0.13 (0.08)
wave5	0.34*** (0.05)	0.32*** (0.05)
age	-0.03*** (0.01)	-0.03*** (0.01)
age_squared	0.0004*** (0.0001)	0.0004*** (0.0001)
age_na	-0.93 (0.79)	-0.91 (0.79)
sex_Female	0.03 (0.03)	0.04 (0.03)
sex_Missing	-1.08** (0.53)	-1.10** (0.52)
ms_Divorced	-0.61*** (0.06)	-0.61*** (0.06)
ms_Single	-0.41*** (0.06)	-0.41*** (0.06)
ms_Widowed	-0.31*** (0.04)	-0.32*** (0.04)
ms_Missing	-0.18 (0.29)	-0.17 (0.29)
es_Unemployed	-0.05 (0.06)	-0.05 (0.06)
es_Housewife	0.12*** (0.04)	0.12*** (0.04)
es_Student	-0.06 (0.05)	-0.05 (0.05)
es_Retired	-0.58*** (0.05)	-0.58*** (0.05)
es_Other	-0.34*** (0.10)	-0.34*** (0.10)
es_Missing	0.09 (0.08)	0.14* (0.08)
in_second step	0.07 (0.06)	0.07 (0.06)
in_Third step	0.19*** (0.05)	0.20*** (0.05)
in_Fourth step	0.45*** (0.05)	0.45*** (0.05)
in_Fifth step	0.59*** (0.05)	0.59*** (0.05)
in_Sixth step	0.74*** (0.06)	0.74*** (0.06)

in_Seventh step	0.98*** (0.06)	0.99*** (0.06)
in_Eigth step	1.09*** (0.07)	1.10*** (0.07)
in_Nineth step	1.04*** (0.09)	1.04*** (0.09)
in_Tenth step	0.96*** (0.09)	0.96*** (0.09)
in_Missing	0.58*** (0.06)	0.58*** (0.06)
ed_Primary	0.33*** (0.07)	0.32*** (0.07)
ed_Secondary	0.60*** (0.07)	0.59*** (0.07)
ed_University	0.67*** (0.07)	0.66*** (0.07)
ed_Missing	0.32*** (0.08)	0.30*** (0.08)
ANS_inc_pm	-0.03*** (0.01)	
ANS_exc_pm		-0.05*** (0.01)
Unemp	-0.01 (0.01)	-0.01 (0.01)
Inflation_rate	0.0002 (0.0002)	0.0003 (0.0002)
log(GNI_PPP)	-0.64*** (0.08)	-0.60*** (0.08)
Constant	13.62*** (0.73)	13.31*** (0.72)
Observations	33,908	33,908
R^2	0.10	0.10
Adjusted R^2	0.10	0.10
Residual Std. Error	2.17	2.17
F Statistic	89.81***	90.28***

See the notes to Table 5.

Table 2.6.3 Group 3 (Wave 2 and 6)

	Dependent variable: SWB	
	Panel model	
	ANS INC PM	ANS EXC PM
	(1)	(2)
cr_Brazil	-0.02 (0.09)	-0.02 (0.09)
cr_Chile	-0.21*** (0.08)	-0.21*** (0.08)
cr_China	-2.14*** (0.16)	-2.15*** (0.16)
cr_India	-3.66*** (0.22)	-3.67*** (0.22)
cr_Mexico	0.11 (0.09)	0.11 (0.09)
cr_Nigeria	-2.97*** (0.14)	-2.98*** (0.14)
cr_South Africa	3.25*** (0.44)	3.25*** (0.43)
cr_South Korea	-1.66*** (0.12)	-1.67*** (0.12)
cr_Spain	3.66*** (0.38)	3.66*** (0.38)
cr_Turkey	-0.36*** (0.11)	-0.36*** (0.10)
wave6	0.75*** (0.07)	0.76*** (0.07)
age	-0.02*** (0.005)	-0.02*** (0.005)
age_squared	0.0003*** (0.0001)	0.0003*** (0.0001)
age_na	0.83** (0.39)	0.83** (0.39)
sex_Female	0.02 (0.03)	0.02 (0.03)
sex_Missing	-0.34 (0.53)	-0.34 (0.53)
ms_Divorced	-0.46*** (0.06)	-0.46*** (0.06)
ms_Single	-0.37*** (0.06)	-0.37*** (0.06)
ms_Widowed	-0.28*** (0.03)	-0.28*** (0.03)
ms_Missing	-0.29 (0.36)	-0.29 (0.36)
es_Unemployed	-0.07 (0.06)	-0.07 (0.06)
es_Housewife	0.08** (0.04)	0.08** (0.04)
es_Student	0.07 (0.05)	0.07 (0.05)
es_Retired	-0.48*** (0.04)	-0.48*** (0.04)

es_Other	-0.07 (0.08)	-0.07 (0.08)
es_Missing	-0.32*** (0.08)	-0.32*** (0.07)
in_second step	0.08 (0.06)	0.08 (0.06)
in_Third step	0.21*** (0.05)	0.21*** (0.05)
in_Fourth step	0.42*** (0.05)	0.42*** (0.05)
in_Fifth step	0.63*** (0.05)	0.63*** (0.05)
in_Sixth step	0.84*** (0.05)	0.84*** (0.05)
in_Seventh step	1.13*** (0.06)	1.13*** (0.06)
in_Eigth step	1.45*** (0.06)	1.45*** (0.06)
in_Nineth step	1.60*** (0.09)	1.60*** (0.09)
in_Tenth step	1.74*** (0.11)	1.74*** (0.11)
in_Missing	0.63*** (0.07)	0.63*** (0.07)
ed_Primary	0.24*** (0.06)	0.24*** (0.06)
ed_Secondary	0.42*** (0.06)	0.42*** (0.06)
ed_University	0.54*** (0.06)	0.54*** (0.06)
ed_Missing	-0.40*** (0.10)	-0.40*** (0.10)
ANS_inc_pm	0.003 (0.004)	
ANS_exc_pm		0.003 (0.004)
Unemp	-0.26*** (0.03)	-0.26*** (0.03)
Inflation_rate	0.002*** (0.0004)	0.002*** (0.0004)
log(GNI_PPP)	-1.14*** (0.08)	-1.14*** (0.08)
Constant	19.56*** (0.85)	19.57*** (0.85)
Observations	37,709	37,709
R^2	0.10	0.10
Adjusted R^2	0.10	0.10
Residual Std. Error	2.16	2.16
F Statistic	99.84***	99.84***

See the notes to Table 5.

Table 2.6.4 Group 4 (Wave 4 and 6)

	Dependent variable: SWB	
	Panel model	
	ANS INC PM	ANS EXC PM
	(1)	(2)
cr_Chile	-0.40*** (0.08)	-0.42*** (0.08)
cr_China	-0.94*** (0.13)	-0.82*** (0.13)
cr_Egypt	-2.14*** (0.10)	-2.09*** (0.10)
cr_India	-1.44*** (0.18)	-1.30*** (0.18)
cr_Japan	-1.17*** (0.10)	-1.22*** (0.10)
cr_Jordan	-0.97*** (0.11)	-0.88*** (0.11)
cr_Kyrgyzstan	-0.84*** (0.18)	-0.79*** (0.18)
cr_Mexico	0.64*** (0.09)	0.63*** (0.09)
cr_Morocco	-0.97*** (0.17)	-0.80*** (0.17)
cr_Nigeria	-1.07*** (0.16)	-0.99*** (0.16)
cr_Pakistan	-1.61*** (0.15)	-1.49*** (0.16)
cr_Peru	-0.75*** (0.11)	-0.73*** (0.11)
cr_Philippines	-0.12 (0.17)	0.07 (0.17)
cr_Singapore	-0.54*** (0.13)	-0.46*** (0.13)
cr_South Africa	-0.04 (0.10)	0.01 (0.11)
cr_South Korea	-1.38*** (0.09)	-1.36*** (0.09)
cr_Spain	-0.09 (0.09)	-0.08 (0.09)
cr_Sweden	-0.04 (0.09)	-0.03 (0.09)

cr_Turkey	-0.65*** (0.08)	-0.64*** (0.08)
cr_United States	-0.40*** (0.12)	-0.48*** (0.11)
wave6	0.35*** (0.03)	0.33*** (0.03)
age	-0.05*** (0.004)	-0.05*** (0.004)
age_squared	0.001*** (0.0000)	0.001*** (0.0000)
age_na	-0.65*** (0.23)	-0.63*** (0.23)
sex_Female	0.05** (0.02)	0.05** (0.02)
sex_Missing	-0.49 (1.01)	-0.49 (1.00)
ms_Divorced	-0.51*** (0.05)	-0.51*** (0.05)
ms_Single	-0.32*** (0.05)	-0.32*** (0.05)
ms_Widowed	-0.25*** (0.03)	-0.25*** (0.03)
ms_Missing	-0.35** (0.17)	-0.34** (0.17)
es_Unemployed	-0.01 (0.04)	-0.01 (0.04)
es_Housewife	0.14*** (0.03)	0.14*** (0.03)
es_Student	0.01 (0.03)	0.01 (0.03)
es_Retired	-0.40*** (0.03)	-0.40*** (0.03)
es_Other	-0.04 (0.06)	-0.04 (0.06)
es_Missing	-0.32*** (0.07)	-0.33*** (0.07)
in_second step	0.12** (0.05)	0.11** (0.05)
in_Third step	0.19*** (0.05)	0.19*** (0.05)
in_Fourth step	0.53*** (0.04)	0.53*** (0.04)
in_Fifth step	0.70*** (0.04)	0.70*** (0.04)
in_Sixth step	0.95*** (0.04)	0.95*** (0.04)
in_Seventh step	1.19*** (0.05)	1.20*** (0.05)
in_Eigth step	1.44*** (0.05)	1.44*** (0.05)
in_Nineth step	1.48*** (0.06)	1.49*** (0.06)
in_Tenth step	1.75*** (0.07)	1.75*** (0.07)
in_Missing	0.82*** (0.05)	0.82*** (0.05)
ed_Primary	0.20*** (0.04)	0.20*** (0.04)
ed_Secondary	0.29*** (0.04)	0.29*** (0.04)
ed_University	0.33*** (0.04)	0.34*** (0.04)
ed_Missing	0.42*** (0.11)	0.42*** (0.11)
ANS_inc_pm	-0.02*** (0.005)	
ANS_exc_pm		-0.02*** (0.005)
Unemp	-0.06*** (0.01)	-0.07*** (0.01)
Inflation_rate	-0.01*** (0.001)	-0.01*** (0.001)
log(GNI_PPP)	0.05 (0.09)	0.10 (0.09)
Constant	7.74*** (0.83)	7.38*** (0.83)
Observations	69,980	69,980
R^2	0.14	0.14
Adjusted R^2	0.14	0.14
Residual Std. Error	2.23	2.23
F Statistic	216.85***	217.11***

See the notes to Table 5

A2.7. Ordered logit model results

Table 2.7.1 Group 4 (Wave 4 and 6)

	Dependent variable:	
	life_satisfaction	
	ANS INC PM	ANS EXC PM
	(1)	(2)
age	-0.06*** (0.01)	-0.06*** (0.01)
age_squared	0.001*** (0.0001)	0.001*** (0.0001)
age_na	-1.49*** (0.41)	-1.48*** (0.41)
sex_Female	0.09*** (0.03)	0.09*** (0.03)
ms_Divorced	-0.45*** (0.08)	-0.45*** (0.08)
ms_Single	-0.42*** (0.07)	-0.42*** (0.07)
ms_Widowed	-0.22*** (0.04)	-0.22*** (0.04)
ms_Missing	-0.18 (0.43)	-0.18 (0.43)
es_Unemployed	0.01 (0.07)	0.01 (0.07)
es_Housewife	0.18*** (0.04)	0.18*** (0.04)
es_Student	-0.20*** (0.05)	-0.19*** (0.05)
es_Retired	-0.50*** (0.05)	-0.49*** (0.05)
es_Other	-0.27** (0.11)	-0.27** (0.11)
es_Missing	-0.02 (0.13)	-0.02 (0.13)
in_second step	0.03 (0.06)	0.03 (0.06)
in_Third step	0.17*** (0.06)	0.17*** (0.06)
in_Fourth step	0.50*** (0.06)	0.51*** (0.06)
in_Fifth step	0.71*** (0.07)	0.71*** (0.07)
in_Sixth step	0.92*** (0.07)	0.91*** (0.07)
in_Seventh step	1.05*** (0.07)	1.05*** (0.07)
in_Eigth step	1.27*** (0.08)	1.27*** (0.08)
in_Nineth step	1.29*** (0.09)	1.29*** (0.09)
in_Tenth step	1.37*** (0.10)	1.37*** (0.10)
in_Missing	0.90*** (0.07)	0.90*** (0.07)
ed_Primary	0.29*** (0.05)	0.29*** (0.05)
ed_Secondary	0.25*** (0.06)	0.25*** (0.06)
ed_University	0.22*** (0.06)	0.22*** (0.06)
ed_Missing	0.37*** (0.12)	0.37*** (0.12)
swb_t0	0.31*** (0.03)	0.29*** (0.03)
ANS_inc_pm	-0.03*** (0.002)	
ANS_exc_pm		-0.03*** (0.002)
Unemp	-0.04*** (0.002)	-0.04*** (0.002)
Inflation_rate	0.0001 (0.0004)	0.0000 (0.0004)
log(GNI_PPP)	0.45*** (0.02)	0.42*** (0.02)
Observations	17,733	17,733
Log Likelihood	-37,156.00	-37,150.73
Note:		*p**p***p<0.01

Table 2.7.2 Group 2 (Wave 2 and 5)

	Dependent variable:	
	life_satisfaction	
	ANS INC PM	ANS EXC PM
	(1)	(2)
age	-0.04*** (0.01)	-0.04*** (0.01)
age_squared	0.0004*** (0.0001)	0.0004*** (0.0001)
age_na	-2.35** (1.02)	-2.32** (1.03)
sex_Female	0.10*** (0.03)	0.10*** (0.03)
sex_Missing	-0.30 (1.27)	-0.27 (1.27)
ms_Divorced	-0.36*** (0.06)	-0.37*** (0.06)
ms_Single	-0.35*** (0.07)	-0.35*** (0.07)
ms_Widowed	-0.20*** (0.04)	-0.20*** (0.04)
ms_Missing	0.07 (0.28)	0.08 (0.28)
es_Unemployed	0.07 (0.06)	0.07 (0.06)
es_Housewife	0.08* (0.05)	0.07 (0.05)
es_Student	-0.33*** (0.05)	-0.32*** (0.05)
es_Retired	-0.41*** (0.05)	-0.40*** (0.05)
es_Other	-0.54*** (0.09)	-0.52*** (0.09)
es_Missing	-0.40*** (0.09)	-0.38*** (0.09)
in_second step	0.12* (0.06)	0.13** (0.06)
in_Third step	0.20*** (0.06)	0.21*** (0.06)
in_Fourth step	0.34*** (0.06)	0.35*** (0.06)
in_Fifth step	0.57*** (0.06)	0.58*** (0.06)
in_Sixth step	0.75*** (0.06)	0.76*** (0.06)
in_Seventh step	0.98*** (0.07)	0.99*** (0.07)
in_Eigth step	1.04*** (0.08)	1.04*** (0.08)
in_Nineth step	1.13*** (0.12)	1.12*** (0.12)
in_Tenth step	1.10*** (0.11)	1.06*** (0.11)
in_Missing	0.53*** (0.06)	0.49*** (0.06)
ed_Primary	0.31*** (0.06)	0.30*** (0.06)
ed_Secondary	0.38*** (0.06)	0.37*** (0.06)
ed_University	0.22*** (0.07)	0.22*** (0.07)
ed_Missing	-0.05 (0.22)	-0.05 (0.22)
swb_t0	-0.30*** (0.04)	-0.36*** (0.04)
ANS_inc_pm	-0.04*** (0.003)	
ANS_exc_pm		-0.05*** (0.003)
Unemp	-0.03*** (0.003)	-0.03*** (0.003)
Inflation_rate	0.001*** (0.0001)	0.001*** (0.0001)
log(GNI_PPP)	0.34*** (0.02)	0.31*** (0.02)
Observations	16,831	16,831
Log Likelihood	-33,564.99	-33,541.91
Note:		*p**p***p<0.01

Table 2.7.3 Group 3 (Wave 2 and 6)

	Dependent variable:	
	life_satisfaction	
	ANS INC PM	ANS EXC PM
	(1)	(2)
age	-0.02*** (0.01)	-0.02*** (0.01)
age_squared	0.0002*** (0.0001)	0.0002*** (0.0001)
age_na	0.62* (0.37)	0.62* (0.37)
sex_Female	0.01 (0.03)	0.01 (0.03)
sex_Missing	-0.42 (0.94)	-0.42 (0.94)
ms_Divorced	-0.24*** (0.07)	-0.24*** (0.07)
ms_Single	-0.25*** (0.07)	-0.25*** (0.07)
ms_Widowed	-0.17*** (0.04)	-0.17*** (0.04)
ms_Missing	-1.04*** (0.39)	-1.04*** (0.39)
es_Unemployed	-0.03 (0.06)	-0.03 (0.06)
es_Housewife	0.03 (0.04)	0.03 (0.04)
es_Student	-0.05 (0.06)	-0.05 (0.06)
es_Retired	-0.27*** (0.04)	-0.27*** (0.04)
es_Other	-0.22*** (0.07)	-0.22*** (0.07)
es_Missing	-0.35*** (0.06)	-0.35*** (0.06)
in_second step	-0.17*** (0.07)	-0.17*** (0.07)
in_Third step	-0.34*** (0.06)	-0.34*** (0.06)
in_Fourth step	-0.22*** (0.06)	-0.22*** (0.06)
in_Fifth step	-0.03 (0.06)	-0.03 (0.06)
in_Sixth step	0.16*** (0.06)	0.16*** (0.06)
in_Seventh step	0.44*** (0.06)	0.44*** (0.06)
in_Eigth step	0.88*** (0.07)	0.88*** (0.07)
in_Nineth step	1.24*** (0.10)	1.24*** (0.10)
in_Tenth step	2.17*** (0.13)	2.17*** (0.13)
in_Missing	0.27*** (0.08)	0.27*** (0.08)
ed_Primary	0.33*** (0.06)	0.33*** (0.06)
ed_Secondary	0.40*** (0.05)	0.40*** (0.05)
ed_University	0.34*** (0.06)	0.34*** (0.06)
ed_Missing	0.69*** (0.26)	0.69*** (0.26)
swb_t0	0.14*** (0.04)	0.14*** (0.04)
ANS_inc_pm	0.001 (0.002)	
ANS_exc_pm		0.001 (0.002)
Unemp	-0.04*** (0.002)	-0.04*** (0.002)
Inflation_rate	0.002*** (0.0001)	0.002*** (0.0001)
log(GNI_PPP)	0.37*** (0.02)	0.37*** (0.02)
Observations	21,035	21,035
Log Likelihood	-42,653.07	-42,653.19
Note:		*p**p***p<0.01

Table 2.7.4 Group 4 (Wave 4 and 6)

	Dependent variable:	
	life_satisfaction	
	ANS INC PM	ANS EXC PM
	(1)	(2)
age	-0.03*** (0.004)	-0.03*** (0.004)
age_squared	0.0003*** (0.0000)	0.0003*** (0.0000)
age_na	-0.27 (0.25)	-0.27 (0.25)
sex_Female	-0.02 (0.02)	-0.02 (0.02)
sex_Missing	-0.24 (0.96)	-0.24 (0.96)
ms_Divorced	-0.32*** (0.05)	-0.32*** (0.05)
ms_Single	-0.26*** (0.05)	-0.26*** (0.05)
ms_Widowed	-0.21*** (0.03)	-0.21*** (0.03)
ms_Missing	-0.25 (0.21)	-0.25 (0.21)
es_Unemployed	-0.04 (0.04)	-0.04 (0.04)
es_Housewife	0.13*** (0.03)	0.13*** (0.03)
es_Student	0.03 (0.04)	0.03 (0.04)
es_Retired	-0.17*** (0.04)	-0.17*** (0.04)
es_Other	-0.04 (0.06)	-0.04 (0.06)
es_Missing	0.26*** (0.05)	0.26*** (0.05)
in_second step	-0.09* (0.05)	-0.09* (0.05)
in_Third step	-0.17*** (0.05)	-0.17*** (0.05)
in_Fourth step	0.04 (0.04)	0.04 (0.04)
in_Fifth step	0.23*** (0.04)	0.23*** (0.04)
in_Sixth step	0.39*** (0.04)	0.39*** (0.04)
in_Seventh step	0.66*** (0.05)	0.66*** (0.05)
in_Eigth step	1.01*** (0.05)	1.01*** (0.05)
in_Nineth step	1.38*** (0.08)	1.38*** (0.08)
in_Tenth step	2.13*** (0.09)	2.13*** (0.09)
in_Missing	0.46*** (0.06)	0.46*** (0.06)
ed_Primary	0.35*** (0.04)	0.35*** (0.04)
ed_Secondary	0.42*** (0.04)	0.42*** (0.04)
ed_University	0.45*** (0.04)	0.45*** (0.04)
ed_Missing	0.49*** (0.16)	0.50*** (0.16)
swb_t0	0.37*** (0.01)	0.37*** (0.01)
ANS_inc_pm	-0.01*** (0.001)	
ANS_exc_pm		-0.01*** (0.001)
Unemp	-0.01*** (0.002)	-0.01*** (0.002)
Inflation_rate	0.01*** (0.001)	0.01*** (0.001)
log(GNI_PPP)	-0.04*** (0.01)	-0.04*** (0.01)
Observations	36,316	36,316
Log Likelihood	-74,125.48	-74,126.72
Note:		*p**p***p<0.01

Chapter 8: Conclusion

Preface to Pezzey (1992).

The decade of the 1980s has witnessed a fundamental change in the way governments and development agencies think about environment and development. The two are no longer regarded as mutually exclusive. It is now recognized that a healthy environment is essential to sustainable development and a healthy economy. Moreover, economists and planners are beginning to recognize that economic development, which erodes natural capital, is often not successful. Quite the contrary. Development strategies and programs which do not take adequate account of the state of critical resources-forests, soils, grasslands, freshwater, coastal areas and fisheries--may degrade the resource base upon which future growth is dependent.

The broad concept of sustainable development was widely discussed in the early 1980s, but was placed firmly on the international agenda with the publication of Our Common Future in 1987, the report of the World Commission on Environment and Development. While the term "sustainability" has been widely used since then, little attempt has been made to translate this concept into an analytical framework that can be used in the development of "sustainable" economic policies. This paper attempts to analyze the concepts of sustainable development, sustainable resource use and sustainable growth in terms of conventional economic analysis, to examine why free market forces may not achieve sustainability, and to explain how policy interventions may help or hinder the achievement of sustainability.

Mohamed T. El Ashry, Director, Environment Department, The International Bank for Reconstruction and Development World Bank 1992.

Written in 1992 in a spirit of great promise and urgency, we remain in many ways today, no further forward in acknowledging and resolving the challenges identified. The statement that, since the 1980s, there has been a 'fundamental change in the ways governments and development agencies think about environment and development', may be true, to some extent, but some 26 years later the challenges are now orders of magnitude larger, not smaller. In this conclusion, we identify the extent to which the content of this thesis highlights any progress in the areas identified with specific attention paid to New Zealand.

Economic growth remains a fundamentally important topic in economics. One key government goal, not least because of the importance of providing public goods, and redistributing wealth is to raise tax revenue without actually increasing tax rates, and the owners and employees of corporations are promising providers. Economic growth helps achieve this goal. In addition, corporations provide employment which is another goal of the state. Corporations are always under pressure to beat the competition while producing the highest returns for lenders and investors. In order for the bulk of them to do so, they require rising consumption levels and recently the media is playing a vital role in creating a drive for mass consumerism powered by modern advertisement methods to influence consumer psychology.[88] Modern advertisements are known to create needs among people by triggering a wide range of emotions, for instance, longing for luxury, fear of being left behind, and so on. New models of products and luxurious services are continuously introduced to keep the plane of mass consumerism flying (Corner & Pels, 2003). To push their goal of continuous growth further, corporations influence the agendas of political parties (Aggarwal, Meschke, & Wang, 2012, Hansen & Mitchell, 2000). Consequently, this increases the possibilities of governments ending-up serving corporate interests better than the individuals' well-being, particularly in developing countries (Porter & Kramer, 2006, Rodriguez et al., 2006).

However, mass consumerism may not favour the planet. There are limits imposed by finite resources to support ever increasing production, including the limited capacity of the planet to assimilate waste generated during the production processes and by the disposal of materials after consumption at the end of their life. Some politicians understand the shortcomings of growth and have been trying to find better ways to describe it. For instance, Barack Obama, in 2010, has called for "long-term lasting growth"[89]; David Cameron, a year later in 2011, for "balanced growth"[90]; and Angela Merkel for "sustainable growth"[91] in 2017. José Manuel Barroso wants "smart, sustainable and inclusive growth" for EU[92]. We clearly want something better than just growth because growth is not enough as a goal of what we want to achieve.

On the other hand, despite massive economic growth historically, many countries in the world have been left behind. The things we fundamentally care about to lead a dignified life such as deprivation, environmental degradation, inequality and so on are not always coming along (Raworth, 2017). Simon Kuznets, the inventor of GDP himself, warned "the welfare of a nation can scarcely be

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[88] There is plenty of research showing higher levels of income give people to freedom to choose what they value in their lives as discussed in the earlier chapters of this thesis. A significant part of what they value is reflected in their buying preferences as Freud (2003) argue individuals transform themselves positively every time they buy what they like. This idea is successfully propagated on media that more products and services you buy, happier you become.

[89] https://www.gpo.gov/fdsys/pkg/DCPD-201000110/pdf/DCPD-201000110.pdf

[90] Governance for growth report by David Cameron published in 2011 available at: http://www.g20.utoronto.ca/2011/2011-cameron-report.pdf

[91] https://www.bundesregierung.de/breg-en/issues/growth-must-be-sustainable-says-angela-merkel-1122572

[92] https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:2020:FIN:EN:PDF

inferred from a measure of national income" in his report to the US Congress in 1934. According to FAO (2018), global GDP has grown approximately 7 times from 11.21 trillion USD in the 1960s to 80 trillion USD in 2016, yet there are still 815 million hungry people on the planet, and another two billion people suffer from micronutrient deficiencies. Ecosystem services that provide the foundation for food production are under severe pressure. About 70% of freshwater is withdrawn for agriculture and clean drinkable water is scarce in many countries of the world. Thus, this double-sided challenge to meet the basic needs for everyone within the means of the planet turns into a debate of sustainable well-being or sustainability and well-being.

Sustainability and well-being are complex, multi-dimensional and interdisciplinary subjects. Both sustainability and well-being emerged as independent subject matters prior to becoming inter-related, or more precisely, unified subject matters. (Qasim, 2017). The debate of sustaining intergenerational well-being in economics goes beyond growth models and find its roots in the notion of total wealth per capita (in terms of total capital stocks) as opposed to income per capita (flows). Total wealth is broadly defined as the stocks of various types of capitals e.g. human capital, produced capital, social capital, natural capital etc. in monetary terms in an economy (Blum, Ducoing, & McLaughin, 2017, Blum, McLaughlin, & Hanley, 2013, Greasley et al., 2014, Hanley, Dupuy, & McLaughlin, 2015).

We conducted an intensive review of literature coupled with modern bibliometric, scientometric and text analysis methods to synthesise the maximum possible dimensions of SaW from the interdisciplinary literature. One of the key insights from this exercise is that SaW models differ significantly in terms both theoretically and empirically with regards to defining the scope and interactions between various types of capitals, particularly natural capital. Because of the unique characteristics of some forms of natural capital in providing life-supporting services (such as drinkable water, breathable air, food etc.), its role and use in development are viewed differently by the various school of thoughts resulting in two opposing broad categories of sustainability: (i) strong sustainability (ii) weak sustainability. Proponents of the former argue that since natural capital cannot be replaced with any other type of capital due to its unique characteristics, all other types of capital should develop independently from natural capital. The later approach supports "Hartwick rule" as a sustainability condition which states that as long as income from the non-renewable natural resources is reinvested to develop the other types of capital in order to maintain or increase total wealth, a country is on sustainable development path (Hartwick, 1977).

Both of these approaches have been criticised in the literature due to their limitations. Strong sustainability, for instance, has been subjected to criticism for neglecting the resilience of natural capital to replenish itself (if it is harvested under certain limits) and the waste of unused natural capital through natural processes. On the other hand, weak sustainability is criticised for its assumption permitting substitution of natural capital with other types of capital. We argue, instead of taking either of these extreme positions, sustainability policies should be guided by a balanced approach, in which substitution between various types of capitals is allowed in order to develop national wealth effectively. Nevertheless, this approach is subject to critical limits to adhere with strong sustainability conditions with a clear understanding of margins to substitute various types of capitals without hitting tipping points or going past the point of no return (Qasim, 2018).

Conflicting SaW definitions are not confined to the academic literature, they are also widely observed in policy documents and in the debates of policymakers (as discussed in Chapter 5). We analysed the text data of more than 120 years from New Zealand policy documents and parliamentary debates. Our analysis shows terms "sustainability" and "wellbeing" (with other related terms) have been used significantly differently over the years by different political parties in power in New Zealand. Worth noting results are:

- Usage of the terms "wellbeing" or "welfare" gained momentum in the mid-1930s when the Labour government was first elected and was used in a range of social contexts such as family welfare, childrens welfare etc.
- The terms "sustainability" and "wellbeing" were used independently before the 1970s; and following the surge in reference to "sustainability" in late the 1970s, find SaW co-occurring.

- There have been periods when the word sustainability was purged from political vocabulary because of its vague definition particularly by the National Party's government and replaced it with the word "resilience".

We argue that resilience and sustainability are not the same things. The word "sustainability" is sometimes substituted for with resilience, but are they the same thing? Roots of the word "Resilience" are found in the Latin word resilire (which means "jump back", "rebound"). In economics, it is the capability to recover from adversity. For instance, recovery from temporary shocks (e.g. sudden flows of migration, or from continuous threats e.g. the ageing of societies), either returning to the initial state or shifting to a new equilibrium (from positive adaptation to transformation) (Stiglitz, Fitoussi, & Durand, 2018). In contrast, sustainability remains the ultimate objective of all development endeavours. Therefore, focusing on resilience should not be misunderstood as an attempt to abandon sustainability, but instead as an approach to retain or restore it when responding to shocks and threats. Sustainability is and remains the ultimate objective. If a resilient system rebounds from a shock to its initial path, this is not good enough if the initial path was unsustainable. While resilience and sustainability are not interchangeable concepts, addressing resilience of systems is a way to build a system-level "macro-prudential" approach about how we can prevent and adapt to shocks and threats or transform our society.

These conflicting approaches to the same end *"sustainable well-being"* have resulted in the development of numerous indicators encompassing SaW ranging from single indicators dealing with any particular dimension of SaW such as real income, health, etc. to complex composite indicators such as HDI, LCA, LCC, EF, GS and so on (see Chapter 3 for details). Recently countries which are focusing to guide national policies with intergenerational sustainability at the core are inclined to adopt dashboards of interlinked indicators instead of a particular indicator or set of indicators as policy guiding tools. Some examples of such frameworks include SEEA, SNA, OECD's better life index, and Distributional National Accounts (DINA)[93]. However, most of these dashboards are either under

[93] OECD's Distributional national accounts (DINA) aims to integrate micro and macro level wealth distribution indicators into an annual database of all countries (for details see Fancundo et al., 2018).

development or are comprised on many indicators which are not actually linked. For example, the World Bank's WDI database has over 1300 development indicators and most of them are independent matrices of certain SaW dimension e.g. primary enrolment, labour force participation etc. The problem with a dashboard comprised of such disconnected indicators is that they can raise warnings going past limits (e.g. savings rates are below critical limits). However, they are not very helpful in tracing the underlying causes.

Genuine savings (GS), in contrast, relates to the capital stock approach, and is a set of nested equations capable of identifying the underlying causes of unsustainable periods over a long period of time. For instance, unsustainable savings rates (or saving gaps) can be easily identified from the estimates with reason which could either be (an undesired) decline in income from natural capital, fluctuation in prices or (a desired) increased level of investments to develop human capital or produced capital for future. GS was first proposed by Pearce & Atkinson (1993)[94] 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 maintain total wealth and to achieve non-declining well-being over time*. In other words, an economy, which saves more than the combined depreciation of its stocks of natural capital and produced capital will be (weakly) sustainable (Pearce & Atkinson, 1993, Pearce, Markandya, & Barbier, 1989). Whenever GS takes negative values, it indicates that the economy is on an unsustainable development path (in terms of the definition by Pearce et al. 1989).

We constructed long-term timeseries of GS to assess how sustainable New Zealand has been through the course of 65 years from 1950 to 2015 and tested it to predict changes in future per capita income in real terms (as an indicator of objective well-being). The World Bank has been publishing annual GS estimates since 1999 (Hamilton, 2005)[95]. However, key problems with the World Bank estimates

[94] Since then, it has become one of the more commonly used indicators of sustainable development over the long-run (Arrow, et al. 2012, Blum et al., 2017, Greasley et al., 2014, Hamilton & Clemens, 1999, Pezzey, 2004). Although GS, for being an indicator weak sustainability, has been criticized for overlooking the tipping points imposed by strong sustainability, Qasim 2018 argues as long as a country operates in the intersections of triple-bottom-line model of weak sustainability, it inherently follows the conditions of strong sustainability.
[95] GS data series goes back to 1970, however, the estimates are not available for many countries in the early years because of data unavailability (World Bank databank: https://data.worldbank.org/indicator/NY.ADJ.NNAT.GN.ZS).

include: (i) they are not available for several years for many countries because of missing data (ii) key aspects are ignored in the calculating GS to maintain comparability across countries (e.g. forestry). Key contributions of our work include GS estimates for New Zealand where we: Firstly, construct GS estimates for an extended period over 1950 – 2015 and then test 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 years).

Our results on GS suggest that New Zealand has been sustainable (from a weak sustainability perspective) by maintaining an average GS to GDP ratio at 17% which is sufficient to meet generalised “Hartwick” rule overtime even without a contribution from exogenous technological advancement. However, when the population growth rate is taken into the account through “wealth dilution effects”, the results suggest that per capita wealth is on the decline as the population growth rates outrun wealth formulation. This finding is consistent with the second element of the World Bank (2011) 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.”*

Such results exhibit 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. In addition, New Zealand has experienced a savings gap (how much a country should have saved for a given population less actual savings i.e. where positive is bad and negative good) of 0.5% over this period with the decade 2000-2010 exhibiting a +7.2% average GS gap as a percentage of GNS. Our results further highlight that New Zealand has experienced year-on-year increases in human, fixed and renewable natural capital assets that are internationally comparatively low (and typically are 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. These results have important policy implications including,

First and foremost, wealth per capita has been declining in New Zealand leading to a savings gap of 0.5% mainly due to population growth rate is higher than that of the wealth creation. We need to understand what policies have resulted in this savings gap.

Secondly, technological advancement did not show a significant contribution to wealth generation as opposed to other OECD countries like Australia, Germany and Britain. This emphasises the need to advance technology to attain higher productivity so that its impact becomes visible particularly in the short-run.

Thirdly, non-renewable natural capital was the area with the highest growth rates, which in part was reversing the savings gaps in the 1980s, and the 1990s. 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 capital which has shown downward trends) to compensate for the decline in the growth of non-renewable natural capital exploitation, which is likely to encounter longer-term environmental resistance.

Finally, forestry (including the standing stock of timber) has been a major contributor to the GS rates. In future, if more land is allocated to forestry will increases in the stocks of renewable natural capital. However, it may lead to competition between forestry and other industries such as dairy farming, horticulture etc. Furthermore, the opportunity cost to increasing forest area by planting native forest (which cannot be harvested by law) would likely be significant and may impact on the future growth of other capitals such as produced capital.

In addition to constructing long-term GS series for New Zealand and testing them as a predictor of changes in future well-being at the national level (i.e. changes in real income per capita), we tested the predictive power of GS (referred to ANS in the corresponding Chapter 7) to explain future changes in subjective well-being in a global context. One of the key findings of this work is that ANS has a negative relationship with subjective well-being in the short-run, however, this relationship turns positive in the long-run. This is consistent with the dynamics of a typical political economy in which governments tend to overlook long-term sustainability in favour of short-term development to demonstrate as their success in order to get more votes in the next elections and stay in power for a longer period.

In conclusion, from this work as a whole, the characteristics of sustainable development from fully researched Brundtland's definitions and elaborated work on GS to monitor it over the long-run elucidate the trajectories of sustainable development path for economies. However, operationalising sustainable development ubiquitously over the long-run under various political regimes is as intractable as the sustainability challenge itself. In the case of New Zealand, for instance, shifting the focus from sustainability to resilience will not resolve this intractability and perhaps worsen it. A resilient economic growth will focus upon creating an economy that can recover from external (or internal) shocks but remains on the current weakly unsustainable growth trajectory, where wealth dilution has, and is leading to, significant savings gaps.

In terms of ways forward and future research, first and foremost, we need to understand the complexities of sustainability and well-being within the closed planetary boundaries; and the sustainability challenge is not a single solution problem either. In a world where countries are acting in their own, rational, self–interest, seem unwilling to embark upon changes in economic behaviour (at the individual, national and international level), which they see as reducing their own current and future wellbeing. Thus, the sustainability challenge is not confined to one particular country, or a nation rather *collective resource use* and *collective footprints* become an important issue going forward to ensure *sustainable well-being, sustainably*. The United Nations Economic Commission for Europe has noted *"… [Sustainable Development Indicator] sets should reflect the transboundary impacts of sustainable development, by highlighting how a country* *in the pursuit of the well-being of its citizens may affect the well-being of citizens of other countries."* (UNECE, 2013 p. 5).

If the ultimate purpose of all development endeavours is to attain the fundamental level of human well-being and increase or at least maintain it over time, then we need to move away from degenerative economic systems[96] built around the notion of everlasting growth to complex regenerative economic systems[97] built on the philosophy of human welfare at its core. A society in which people thrive no matter if it grows or not. Raworth (2017) has used an analogy of a doughnut shown in Figure 2 as one way to envisage such a system. People in the middle hole are facing the shortfall of fundamental human needs. They don't have enough food, clean water, shelter, health, education, etc. to lead a dignified life. The twelve dimensions of the social foundation are set out by internationally agreed minimum social standards in UN's Sustainable Development Goals (SDGs) in 2015. We want to elevate the disadvantaged above the social foundation in the green circle. But we cannot let our ***collective resource use*** and environmental burdens go beyond the ecological ceiling (the outer boundary of the doughnut)[98]. Humanity can safely thrive between the social foundation and planetary boundaries.

In doing so, one can ask a rudimentary question like, 'what agencies are the custodians of SGDs to deliver fundamental human well-being globally?' How effective are their roles to operationalise SDGs? What protocols are in place to keep the *collective footprint* within the limits internationally?

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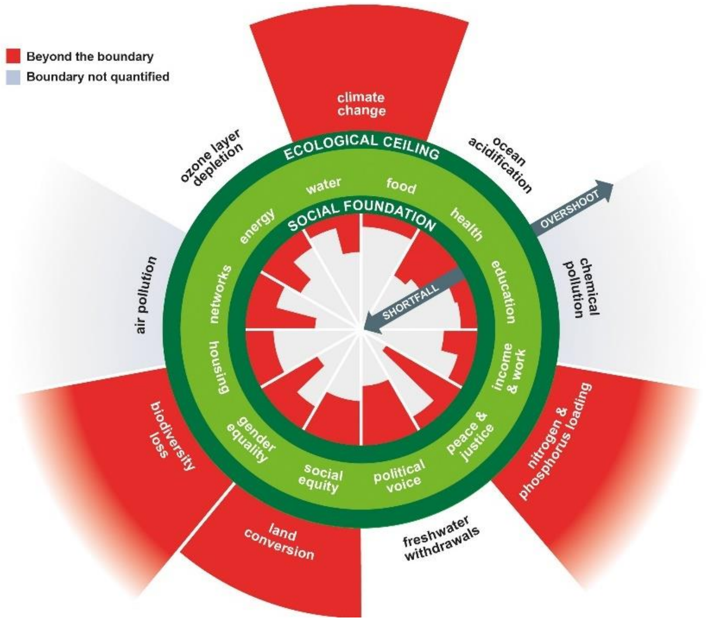
[96] An economy in which non-renewable materials are extracted from the planet, turned into useful products which become obsolete quickly and the waste is dumped into the environment and the cycle continues to push us towards planetary boundaries.

[97] An economy with endless recycling processes where resources are never used up; waste from one process becomes the input for another; an economy which runs on renewables; and where knowledge is distributed to unleash infinite possibilities of innovation without boundaries.

[98] The ecological ceiling consists of nine planetary boundaries beyond which environmental degradation can lead to irreversible damages to the life-supporting services of the planet (Rockström et al., 2009).

Figure 1: Doughnut of social and planetary boundaries



Source: https://www.kateraworth.com/doughnut/

In this figure, we can see that we are facing a shortfall in all twelve-social foundation. Some shortfalls are severe than others. Whereas, we are already overshooting four out of nine planetary boundaries to unsafe operating zone for life through climate change, biodiversity loss, land conversion and pollution from nitrogen and phosphorus.

What if a country refuses to abide by those protocols?[99] On the monitoring and evaluation side, how can we expand our current measures of sustainability (e.g. GS) to take dynamic relationship between prices, taxes, subsidies and investments into the account to ration out scarce resources and to indicate when (or whether) they should be reused or scrapped (e.g. does it make sense to recycle something at vast cost or to dump it?). Eventually, how can the current growth-oriented democratic system be auto-correcting before pushing humanity to the verge of extinction?

[99] For example, US did not sign Kyoto Protocol in 1992 to limit their greenhouse gas emissions and 20 years later again the country with largest emissions per capita (US) and the country the largest net emissions (China) ratified from Paris agreement (Pickering et al., 2018). If such countries continue to exploit the only life-supporting planet in the entire solar system from the depth of the oceans to the space above skies, and resultantly humanity suffers who should be held responsible for that?

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Chapter 4.1: "What Came First – Wellbeing or Sustainability?" A Systematic Analysis of The Multi-Dimensional Literature Using Advanced Topic Modelling Methods

Nature of contribution by PhD candidate	Data analysis, literature review and paper drafting.
Extent of contribution by PhD candidate (%)	80

CO-AUTHORS

Name	Nature of Contribution
Les Oxley	Proof reading, editing, technical support, expert opinion.

Certification by Co-Authors

The undersigned hereby certify that:

- the above statement correctly reflects the nature and extent of the PhD candidate's contribution to this work, and the nature of the contribution of each of the co-authors; and

Name	Signature	Date
Les Oxley	Oxley	19/12/18

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Chapter 6: Genuine savings as a test of New Zealand weak sustainability

Nature of contribution by PhD candidate	Data analysis, literature review and paper drafting.
Extent of contribution by PhD candidate (%)	70

CO-AUTHORS

Name	Nature of Contribution
Les Oxley	Proof reading, editing, technical support, expert opinion.
Eoin McLaughlin	Technical support for conducting genuine savings estimates.

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Chapter 7: Sustainable economic policy and well-being: The relationship between adjusted net savings and subjective well-being

Nature of contribution by PhD candidate	Data analysis, literature review and paper drafting.
Extent of contribution by PhD candidate (%)	80

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The undersigned hereby certify that:

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