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Approaches to accounting for our natural capital: Applications across Ireland

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Luke McGrath & Stephen Hynes

Abstract

Natural capital accounting allows for the integration of our natural assets within economic and political decision making, can improve natural resource governance and permits the development of environmentally adjusted macroeconomic indicators to serve as complements to Gross Domestic Product (GDP). The United Nations System of Environmental-Economic Accounting (UN SEEA) is the accepted international standard for natural capital accounting, providing a framework for organizing and presenting statistics on the environment and its relationship with the economy. This paper details different approaches to natural capital accounting, all related to the SEEA framework, currently being undertaken across Ireland. We discuss the relationship between natural capital accounts and sustainable development measurement and provide recommendations for future work in these areas.

Declarations of interest: None

Keywords: Green accounting; natural capital; wealth accounting; environmental-economic accounting; sustainable development, ecosystem services.

1. Introduction

A nation's economic accounts are prepared in line with the United Nations System of National Accounts (SNA). These accounts provide comparable and objective information that public and private decision-makers routinely rely upon. The SNA fails to adequately account for natural capital. Natural capital represents the stock of renewable and non-renewable natural resources that combine to yield a flow of ecosystem services (Pearce and Atkinson, 1995). It is widely recognised that the SNA provides an incomplete picture of economic development and is deficient for environmental policy (Nordhaus & Tobin, 1973; Ahmad et al., 1989; Repetto et al. 1989; Hartwick 1990; Dasgupta, 2001).

Since at least Ayres and Kneese (1969), economists have argued that the source of environmental problems lies in a failure to account for the valuable services provided by our natural environment. The aggregates of the SNA such as Gross Domestic Product (GDP) represent the traditional economic growth metrics but omit important environmental assets. Accounting for natural capital offers a way to embed our natural assets within the realm of political and economic decision-making, can improve natural resource governance and permits the development of environmentally adjusted macroeconomic indicators to serve as complements to GDP. For the European Union (EU), these issues cannot be ignored not least because of the importance for environmental protection but because the European Commission has made steps toward environmental accounting a requirement under Regulation (EU) 691/2011 (as amended by Regulation (EU) No 538/2014). Natural capital accounts must be prepared as they are vital for the EU to measure progress in relation to its economic development objectives as set out by the Europe 2020 and Sustainable Development strategies, as well as its Biodiversity strategy.[1] The objective of this paper is to discuss the link between natural capital accounting and sustainable development measurement and to critique various approaches to natural capital accounting that are being undertaken across Ireland. We provide recommendations for future development in these areas.

The United Nations System of Environmental-Economic Accounting (SEEA) provides a framework for organizing and presenting statistics on the environment and its relationship with the economy using an internationally agreed set of standard concepts and definitions. The SEEA

[1] For information on the Europe 2020 strategy see here: https://ec.europa.eu/eurostat/web/europe-2020-indicators. For information on the Sustainability Strategy see here: https://ec.europa.eu/environment/sustainable-development/strategy/index_en.htm. For information on the Biodiversity Stragey see here: https://ec.europa.eu/environment/nature/biodiversity/strategy/index_en.htm.

outlines the various approaches to natural capital accounting. The foundations of SEEA lie in efforts to develop “green” accounts and to aid in sustainable development measurement, which began in the 1970s, (see, Hecht, 2007 for a history). The SEEA framework consists of two key components. Firstly, the Central Framework (SEEA CF) which is designed to be consistent with the SNA and covers the accounts where a wide consensus has emerged. Secondly, the SEEA Experimental Ecosystem Accounting (SEEA EEA) framework. The SEEA EEA complements the SEEA CF and represents efforts toward coherent ecosystem accounting as well as containing the more contentious issues surrounding monetary valuation and alternatives to GDP. A revision of the SEEA EEA is underway and scheduled for completion by the end of 2020. The revised 2014 SEEA CF outlines three basic approaches to natural capital accounting:

1. **Physical flow Accounts** to quantify, in physical terms, flows from the economy to the environment (e.g. emissions of pollutants) and from the environment to the economy (e.g. the felling of trees) for different economic sectors.

2. **Environmental Asset Accounts** to assess the stocks of natural capital in physical (e.g. cubic metres of natural gas) or monetary terms (using the net present value of future flows).[2] The SEEA lists seven categories of environmental assets: mineral and energy resources, land, soil, timber, water, aquatic resources, and other biological resources.

3. **Environmental Expenditure Accounts** to tabulate and separate environmentally-related monetary transactions already recorded in the SNA such as government spending on environmental protection and resource management, the collection of environmental taxes, and expenditures on subsidies.

The United Nations Statistical Commission adopted the SEEA CF as an international standard in 2012 and it is the basis for the EU’s programme of natural capital accounting.[3] In section 3, we detail the work that the Irish Central Statistics Office has carried out in its implementation of the EU programme on natural capital accounting.

Another important approach to natural capital accounting that is outside the SEEA CF but discussed within the SEEA EEA is environmentally adjusted macro-aggregates.

[2] Mineral and energy resources, land, soil, timber, water, aquatic resources, and other biological resources.
[3] See https://ec.europa.eu/environment/nature/capital_accounting/index_en.htm for details of the accounting programme.

Environmentally adjusted macro-aggregates relate to the international research linking natural capital depletion with sustainable economic development which has intensified following the call for complements to GDP that take environmental concerns into account (European Commission, 2009; Stiglitz et al., 2009; UN, 2012). We discuss the link between natural capital accounting and sustainable development in detail in Section 2.

4. **Environmentally Adjusted Macro-Aggregates**: to monetize the damages associated with the depletion of natural resources and environmental quality degradation. This approach uses the SNA as a starting point and then makes adjustments to account for assets omitted from the SNA such as natural capital.

Comprehensive wealth accounts represent an approach to environmentally adjusted macro-aggregates that is directly focused on sustainable development measurement. Comprehensive wealth accounts are based on the economic or "capital approach" to sustainable development (Section 2). Within the capital approach, sustainable development requires the maintenance of comprehensive national wealth for each subsequent generation. Wealth is comprehensive in the sense that it contains all capital assets that individuals obtain well-being from, either directly or indirectly. The conception of capital must therefore be broadened beyond physical capital (machines and infrastructure) to include human capital (education and skills), natural capital (clean air, natural resources) and social/institutional capital (culture and trust).

Changes in comprehensive national wealth are the "Genuine Savings" (GS) of the economy. GS measures, in monetary terms, the annual change in the value of the economy's comprehensive wealth and involves adjusting the SNA aggregates to reflect changes in the stocks of human, physical and natural capital. Declining wealth (negative GS) signals unsustainable development indicating that the current generation is consuming capital assets and diminishing future welfare opportunities even if in the short-term GDP per capita may be rising (Dasgupta and Mäler, 2000; Arrow et al., 2012). GS has emerged as the leading economic indicator of sustainable development (Hanley et al., 2015). We discuss recent research that examines Ireland's GS from 1990-2016 in Section 4.

The remainder of the paper is as follows: Section 2 makes explicit the link between natural capital accounting and various concepts of sustainable development. In section 3, we detail the work that the Central Statistics Office has carried out in its implementation of the EU programme on natural capital accounting. Section 4 details research on Ireland's capital stocks that analyses whether or not these assets have been running down using the environmentally adjusted macro-aggregate Genuine Savings. Section 5 briefly outlines a number of other natural capital projects across the island of Ireland. Concluding remarks are made in Section 6.

2. Sustainable Development and Natural Capital Accounting.

Sustainable development as a policy goal became popularised following the publication of the Bruntland Commission in 1987. The commission provided the seminal if vague definition of sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WECD, 1987). Since the Commission's report, many have attempted to operationalise the concept of sustainable development. The SEEA 2003 outlines three broad approaches to sustainable development.

The three-pillar approach

The three-pillar approach argues that economic, social and environmental systems must be simultaneously sustainable in and of themselves and they are interconnected. Each of the three pillars is considered independently crucial and of equal importance. Operationalising the three-pillar approach would require some independent assessment of economic sustainability, social sustainability and environmental sustainability. The key problems in operationalising the three-pillar approach lie in the definition and assessment of sustainability within each of these pillars and how one might address unsustainability in one pillar without affecting another? The SEEA can provide information relating to environmental and economic systems and the interactions of these systems but offers little with regard to social systems.

The ecological approach

The notion that economic and social systems are sub-systems of the global environment is central to the ecological view. The ecological approach is not anthropocentric. Sustainability requires sufficient capacity of ecosystems to respond with resilience to external shocks. It is the protection and enhancement of ecosystem "health" that ensures the resilience that is necessary for sustainability. Operationalising the ecological approach requires defining and measuring ecosystem health. Measurement is required of ecosystem pressures that are a consequence of human activities and separate measurement of the responses of ecosystems to these pressures. The SEEA-EEA provides much detail for these types of ecosystem accounts but these accounts remain in the early stages of development. However, to have any idea about ecosystem resilience information on the stocks and flows within the economic system and their relationship with the environmental system will be required and this is the focus of SEEA CF.

The capital approach

The capital approach is the concept best suited to harness the power of the SEEA. The capital approach is arguably the most consistent and well-developed approach to sustainable development as it is derived directly from neoclassical economic theory and expanded by integrating concepts from the natural sciences (particularly ecology and physics) and from other social sciences. The capital approach conceptualises a sustainable development path as one that is capable of providing the opportunity for non-declining welfare through time. Productive capacity depends on the broadly defined stock of capital resources, also referred to as comprehensive national wealth. From this perspective, sustainable development is feasible if the economy at least maintains comprehensive wealth through time. The concept echoes back to Hicks (1939) who provided the seminal definitions of income that, in essence, have sustainability built-in. Hicksian income is the amount that one can consume while keeping real wealth intact.[4] At the national level, maintaining comprehensive wealth entails the maintenance of the resource base (stocks of physical, natural, human and social/institutional capital). To operationalise the capital approach measures of comprehensive national wealth and the changes in comprehensive national wealth (Genuine Savings) are required. The key issues involve the measurement and valuation of the various capital stocks and a judgement on the conditions required to achieve sustainability (non-declining wealth through time). There is a strong consensus in the economics literature regarding the concept of sustainable development as non-declining wealth but a debate over the conditions required to achieve non-declining wealth continues. The debate revolves around the two paradigms of “weak” sustainability and “strong” sustainability.

Weak sustainability requires the maintenance of total capital and is conditional on one or more of the following; all capital forms are sufficiently substitutable with each other, technological advancement is such that substitution is a moot point or there exists super-abundant natural resources. Weak sustainability permits the depletion of natural capital but only if this depletion is offset by equivalent or greater increases in other forms of capital. A common unit if measurement

[4] Hicksian income is the maximum amount an individual can consume during a period and remain as well off at the end of the period as at the beginning. Imagine an individual whose only source of income is a trust fund valued at €1 million at the beginning of a year and the fund pays a net return of 10% annually. The individual’s annual income is €100 thousand, as this is the maximum amount that she can consume in a year without depleting the capital investment.

is required to assess if total aggregate capital is being maintained and the best option is monetary units. Genuine Savings (GS) has emerged as the leading indicator of weak sustainability. Negative GS imply declining national wealth and thus an economy that is on an unsustainable development path.

Strong sustainability requires a stronger constraint of non-declining natural wealth as proponents view natural resources as a distinct and non-substitutable form of capital (Costanza et al., 1991; Cabeza-Gutés, 1996). Strong sustainability requires that natural capital stocks be maintained intact independent of other forms of capital. In practice, this requires invoking precautionary principles for the use of natural capital.[5] Because strong sustainability requires the independent maintenance of capital stocks, there is no reason in principle, to measure natural capital in monetary units. In terms of an operational sustainability framework, it appears that strong sustainability would require aggregation of at least some forms of natural capital into a common unit. Without aggregation and substitution within the natural capital stock we could not deplete a single item of natural capital without replacing it with exactly the same form of natural capital. Beckerman (1994) refers to this situation as “absurdly strong sustainability”.

2.1 Do the European Union’s Sustainable Development Indicators measure sustainability?

The European Union has a Sustainable Development Strategy (SDS) that is monitored by Eurostat (COM (2016) 739). Eurostat report on a broad dashboard comprising of 100 indicators set out in terms of the 17 United Nations Sustainable Development Goals (SDGs). (Table 1).[6] In Ireland, the monitoring and reporting of sustainability indicators comes under the remit of the Department for Communications, Climate Action and Environment (DCCAE). The Irish CSO produce a “Sustainable Development Indicators” publication, biannually reporting an indicator set comprising 48 indicators across the economy, social and environment that were developed by DCCAE (Table 2).

[5] Renewable resources should not be used in excess of their natural regeneration; Non-renewable resources should be used prudently and efficiently with care that the same function is available to future generations, say by technological development or shift to use of renewable resources; Sink functions should not be used beyond their assimilative capacities; Activities which cause deterioration in service functions should be avoided or at least minimised.

[6] In 2015, the EU fully committed to delivering on the 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals (SDGs) as outlined in ‘Towards a Sustainable Europe by 2030’.

Table 1: United Nations Sustainable Development Goals**.**

1. No Poverty	**2. Zero Hunger**	**3. Good Health & Well Being**	**4. Quality Education**	**5.**	**6.**	**7. Affordable & Clean Energy**	**8. Decent Work & Economic Growth**	**9. Industry, Innovation & Industry**
10. Reduced Inequalities	**11. Sustainable Cities**	**12. Responsible Consumption & Production**	**13. Climate Action**	**14. Life**	**15.**	**16. Peace & Justice Strong Ins**	**17. Partnerships for the Goals**	

	titutions

These indicators are clearly important but lack a clear interpretation for sustainability assessment. The core issue with these sustainability indicators is that they were not chosen with respect to a coherent model of sustainable development. The UN nor the EU ever define what “sustainable” means. The lack of theoretical rigour lead development economist William Easterly to conclude that the UN Sustainable Development Goals might as well be called the “Senseless, Dreamy, Garbled” or “Some-such Development” Goals (Easterley, 2015). In the context of EU policy, it seems odd that separate indicator systems cover the Lisbon strategy (economic development strategy) and the SDS. There have been numerous attempts to construct an operational sustainability interpretation of the SDGs. Sachs et al. (2018) developed a traffic light system for each nation awarding a green, orange, yellow or red light relating to the progress made for each goal based on an assessment of the accompanying indicators. Other studies have attempted to convert the indicators into an overall index (Costantza et al., 2016; Clark and Kavanagh, 2019). The traffic light system and alternative indices cannot resolve the lack of theoretical rigour. For example, under the capital approach, development is unsustainable if comprehensive national wealth declines. There is no equivalent sustainability interpretation from these alternatives, they merely tell us if some indicators or index went up, down or remained unchanged through time.

Table 2: Irish CSO Sustainable Development Indicators

Economy – 13	Social – 16	Environment -19
1. Dwellings Completions compared to EU 2007-15 2. Dwellings Completions 1970-2015 3. EU Harmonised Index of Consumer Prices 4. Gross Capital Formation 5. Gross R&D expenditures 6. Foreign Exchange Rates 7. Govt. expenditure on pay and social welfare 8. Income tax Distribution 9. Tax Revenues 10. Tax Revenues compared to EU 11. Per capita Net Receipts from EU 12. Per capita, Net Receipts from EU compared across EU **13.** General Government Debt and Balance 1995-2015 % of GDP	14. Tobacco Consumption compared across the EU 15. Alcohol Consumption compared across the EU 16. Obesity Levels in 2014 17. Usual Means for travelling to work 1981-2016 18. Usual Means for travelling to school 1981-2016 19. 2nd and 3rd Level completion rates 1995-2016 20. Average Class size compared across the EU in 2014 21. Pupil-Teacher ratio 1995-2015 22. Life Expectancy 1901-2011 23. Persons aged 80 or above as a percentage of persons aged 65 and above 1926-2016 24. Old-age dependency ratio 1996-2016 25. At risk of poverty across the EU 2007-2015 26. Net migration 1951-2016 27. Migration and emigration 1987-2016 28. Unemployment rate 1985-2016 29. Employment Rate by age class 2000-16	30. Common Bird index 1998-2014 31. Protected Areas under 20154 EU habitats directive 32. Domestic Waste Water Treatment 2002-16 33. Packaging Waste 2001-13 34. Domestic Water Supply Sources 2002-2016 35. Municipal Waste 2001-12 36. New Private Cars Licensed by Emissions Class 2005-2016 37. Private cars per 1000 of population 1985-2016 38. Imported energy dependency 1990-2015 39. Contribution of renewable energy 1990-2015 40. Total primary energy requirement 1990-2015 41. Domestic Building Energy Ratings 2009-2016 42. Nitates in groundwater 1995-2014 43. River water quality 1987-2015 44. EU: Forest Cover 2015 45. GHGs by sector 1990-2015 46. GHGs per capita 47. Emissions of selected pollutants 2015 48. Particulate Matter emissions 1990-2015

2.2 Critique and Recommendations

It is obvious that no single indicator can provide an all-encompassing answer to questions surrounding sustainable development. It is also apparent that the current monitoring of sustainable development in Ireland and across the EU lacks coherence. The SEEA can serve as, at least, a partial framework for measuring sustainable development from all three of the broad approaches discussed. This means that natural capital accounts are important regardless of what definition or concept of sustainability is preferred. However, it is clear that the focus of the SEEA on macroeconomic accounts that integrate environmental and economic data make it particularly useful for the capital approach. For sustainability to be meaningful, it must be achievable and measurable by some reasonably clear metric or metrics (Solow, 1993). The capital approach appears to be the leading contender in this regard, as it derives from economic theory and provides a consistent and theoretically grounded framework for sustainability assessment. If one takes a different view of sustainable development a strong link that preserves the theoretical strength of the capital approach can be maintained through further *additional* indicators that focus on issues such as current well-being, wider social issues and/or ecosystem resilience.

A salient example that seeks to preserve the theoretical framework of the capital approach can be found in the "proposed set of practical indicators" from the UN and others (UN et al., 2008). The proposed set of practical indicators is split between "foundational well-being" and "economic well-being". The foundational well-being metrics relate to some strong sustainability indicators and some social and current welfare indicators. The economic well-being component is effectively total comprehensive wealth and changes in wealth (GS) in disaggregated form. It is easy to imagine how the practical indicator set could be amended to cover other issues (e.g. ecological). Gnegne (2019) offers an alternative portfolio approach that may appeal to advocates of the three-pillar approach. The portfolio contains separate indicators that measure the distinct issues of current well-being (social sustainability), sustainable well-being (economic sustainability) and environmental sustainability. Gnegne (2019) suggested a potential portfolio with current well-being monitored by the Human Development Index, the sustainability of well-being by GS and environmental sustainability by the Ecological Footprint indicator.

Table 3: UN et al. (2008) Proposed Indicator Set.

Indicator Domain	Stock Measure	Flow Measure
Foundational well-being	Health-Adjusted Life Expectancy	Index of changes in age-specific mortality and morbidity
	% of the population with post-secondary education	Enrolment in post-secondary education
	Temperature Deviations	Greenhouse gas emissions
	Ground Level Ozone and Fine Particulate Concentrations	Smog-forming pollutant emissions
	Quality-Adjusted Water Availability	Nutrient loadings to water bodies
	Fragmentation of natural habitats	Conversion of natural habitats to other uses
Economic well-being	Real Per Capita net foreign financial asset holdings	Real per capita investment in foreign financial assets
	Real per capita produced capital	Real per capita net investment in produced capital
	Real per capita human capital	Real per capita net investment in human capital
	Real per capita natural capital	Real per capita net depletion of natural capital
	Reserves of energy resources	Depletion of energy resources
	Reserves of mineral resources	Depletion of mineral resources
	Timber resource stocks	Depletion of timber resources

3. Implementing the SEEA Central Framework

The EU requires all Member States to construct natural capital accounts under Regulation (EU) No 691/2011 (as amended by Regulation (EU) No 538/2014). All Member States must regularly report on the 6 modules included in the Annexes to Eurostat, the European Statistical Office.

3.1 Methodology

At present, the regulations cover six separate modules and relate to various physical flow and environmental expenditure accounts but do not, as of yet, relate to environmental asset accounts. The six modules are (i) air emissions accounts, (ii) environmental taxes, (iii) economy-wide material flows, (iv) environmental protection expenditure, (v) physical energy flows, and (vi) environmental goods and services.[7] The accounts are consistent with the physical flow and environmental expenditure approaches contained in the UN SEEA CF but as of yet the regulations do not cover environmental asset accounts.

3.2 Application

In Ireland, the Central Statistics Office (CSO) is required to submit data for the six modules on an annual basis. The CSO compile other accounts, at least partially, on a voluntary basis.[8] We discuss some examples of physical flow and environmental expenditure accounts constructed by the CSO below.

Physical Flow Accounts

The purpose of physical flow accounts is to record the relationship between the environment and the economy in both directions. A key motivation for flow accounts is to determine how closely economic activity is linked to material inputs and pollution outputs. Air emissions accounts provide a salient example of how flow accounts can influence policy formulation and evaluation. Policymakers require sectoral information in order to enact prudent policies to ensure the achievement of EU targets is met at least cost. Ireland's 2020 target is to achieve a 20% reduction of non-Emissions Trading Scheme (non-ETS) sector Greenhouse Gas Emissions (GHGs) (i.e. agriculture, transport, residential, commercial, non-energy intensive industry, and waste) on 2005 levels. Ireland's 2030 target under the Effort Sharing Regulation is a 30% reduction of emissions compared to 2005 levels by 2030. Over the longer-term Ireland's National Policy Position has set a target of an aggregate reduction in carbon dioxide (CO2) emissions of at least 80% (compared to 1990 levels) by 2050 across the electricity generation, built environment and transport sectors. Ireland must also satisfy limits to non-GHG local air pollutants under the National Emissions Ceilings Directive (NECD).

The CSO publish air emissions accounts that categorise GHG emissions and local air pollutants by economic sector. The air emissions accounts are scrutinised by the Climate Change Advisory Council (CCAC), an independent advisory body tasked with assessing and advising on how Ireland is making the transition to a low carbon economy established under the Climate Action and Low Carbon Development Act 2015, who publish an annual review. Based on the air

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[7] (i), (iii) & (iv) relate to physical flow accounts.

[8] Environmental subsidies, forests, water, land cover and land use, and resource management expenditure.

emissions accounts coupled with projections of future emissions compiled by the Environmental Protection Agency (EPA), *"Ireland will not meet its emissions reduction targets, even with the additional policies and measures included in the National Development Plan"* (CCAC, 2019). Agriculture, forestry and fishing combined with industry comprised the majority of annual GHG emissions through time (Table 4). Total GHGs increased by 3.6% to 61.5 million tonnes of carbon dioxide equivalent from 2015 to 2016 as emissions from all sectors increased. Emissions from agriculture, forestry & fishing, industry, and services have all increased from their 2010 levels. Emissions from households have declined from their 2010 levels.

Table 4: Air Emissions Account

'000 tonnes CO2 equivalent

Economic Sector (NACE Rev 2)	2010	2011	2012	2013	2014	2015	2016
Agriculture, Forestry & Fishing	**18,825**	**18,187**	**18,573**	**19,413**	**19,173**	**19,469**	**20,006**
Industry	**20,953**	**19,026**	**19,954**	**18,783**	**19,247**	**20,289**	**21,191**
Mining and quarrying	284	262	250	271	290	287	327
Food products, beverages and tobacco products	1,280	1,115	1,083	1,199	1,185	1,185	1,154
Textiles, wearing apparel and leather products	14	6	5	10	9	10	10
Wood and paper products and printing	89	45	54	79	76	78	83
Coke and refined petroleum products	311	286	314	295	280	359	314
Chemicals and chemical products	94	93	108	134	119	123	145
Basic pharmaceutical products and pharmaceutical preparations	279	257	256	244	237	245	214
Rubber and plastic products and other non-metallic mineral products	2,410	2,147	2,494	2,424	2,985	3,228	3,456
Basic metals and fabricated metal products, except machinery and equipment)	1,554	1,519	1,499	1,474	1,476	1,483	1,341
Computer, electronic and optical products	239	125	119	131	114	143	163
Electrical equipment	49	42	42	49	52	47	56
Machinery and equipment not elsewhere classified	90	60	57	64	64	64	69
Transport equipment	18	10	11	11	11	11	12
Furniture; other manufacturing; repair and installation of machinery and equipment	172	115	123	134	131	134	124
Electricity, gas, steam and air conditioning supply	12,932	11,573	12,302	10,888	10,701	11,254	12,000
Water supply; sewerage, waste management and remediation activities	789	767	716	867	1,047	1,165	1,213
Construction	349	605	522	509	469	473	510
Services	**6,499**	**6,287**	**6,075**	**6,029**	**6,153**	**6,438**	**6,856**
Households	**14,956**	**13,606**	**13,135**	**13,390**	**12,744**	**13,230**	**13,493**

Total GHG emissions	**61,233**	**57,106**	**57,736**	**57,615**	**57,316**	**59,427**	**61,546**

Source: CSO (2018)

By combining GHG emissions with economic activity data we can examine how closely economic growth is linked with pollution outputs. A simple correlation coefficient reveals a strong positive correlation between Gross National Income (GNI) (in constant prices) and total GHGs of 90% from 1995-2005 and 83% from 2012-2016. On a more positive note, the emissions intensity of GHGs (the level of GHG emissions per euro of Gross National Income) has improved considerably (Fig. 1) and most non-GHG emissions have strongly decoupled from 1995 (see Section 4).

<Figure 1 >

Fig. 1: Emissions Intensity of Greenhouse Gases 2007-2016

The SNA measures the total economic transactions through indicators such as GDP and GNI. There is no equivalent system for measuring the physical material "transactions" in an economy. Economy-wide Material Flow Accounts (MFA), another type of physical flow account, attempt to bridge this gap by describing the interaction of the domestic economy with the natural environment and the rest of the world economy in terms of flows of materials. Only flows crossing the system boundary, as inputs between the environment and the economy or as outputs between the economy and the environment, are included. Material inputs cover extractions of materials (such as mineral ores) and imports of goods (such as fossil fuels). Material outputs represent materials being disposed of into the natural environment as well as the exports of waste material and goods. Domestic Material Consumption (DMC) measures the flow of material being consumed domestically and was estimated at 104.4 million tonnes in 2016 (Table 5). Limestone and gypsum represented the main components of domestic extraction while the largest category of imports were fossil fuels and exports were biomass.[9]

Table 5: Domestic Material Flow Account

million tonnes

Description	200	200	200	201	201	201	201	201	201	201
Domestic Material Consumption	**181.**	**159.**	**121.**	**104.**	**97.**	**90.**	**99.**	**95.**	**96.**	**104.**
Biomass	36.3	38.4	38.2	37.9	37.	37.	39.	39.	38.	37.9
Metallic Minerals	8.7	7.3	6.1	7.0	6.1	6.4	6.2	6.4	6.8	6.2
Non-Metallic Minerals	117.	94.6	60.2	40.4	36.	32.	34.	33.	34.	42.5
Fossil Fuels	17.9	18.0	16.7	18.6	16.	13.	19.	16.	16.	16.8
Other Products	0.9	1.2	0.6	0.5	0.5	0.4	0.6	0.8	0.9	1.0

[1]Regulation (EU) No 691/2011 defines biomass as crops, crop residues, wood and wild fish catch, aquatic plants/animals, hunting and gathering.
Source: CSO (2018)

Information on material flows can be combined with data on economic activity to measure resource productivity. Resource productivity (GDP/DMC) quantifies the relation between economic activity and the consumption of natural resources and sheds light on the extent of decoupling. Resource productivity has increased considerably from €1.08 per kg in 2007 to €2.62 in 2016 (Fig. 2).

<Figure 2 >

Fig. 2: Resource Productivity (GDP/DMC) 2007-2016

Environmental Expenditure Accounts

The environmental expenditure accounts tabulate environmentally-related monetary transactions, such as the amount of spending on environmental protection, damaging subsidies and the collection of environmental taxes. Table 6 presents the CSO's environmental tax accounts for Ireland. An environment tax is defined by Regulation (EU) 691/2011 as "*A tax whose tax base is a physical unit (or a proxy of a physical unit) of something that has a proven, specific negative impact on the environment, and which is identified in the European System of Accounts as a tax.*"

€5.2bn of environment-related taxes were collected in 2017. The majority of environment taxes were recovered through energy taxes (62% of the 2017 total) and transport taxes (37% of the 2017 total). Energy taxes include taxes on energy production and products, with the majority recovered from taxes on fuels. Pollution and resource taxes are extremely small (1% of the 2017 total) but this is largely explained through the treatment of carbon taxes as an energy tax to aid international comparability. Pollution taxes include those levied on water, management of solid waste and noise. Resource taxes relate to natural resource extraction although taxes on land and those designed to capture resource rents are generally not recorded. Transport taxes relate to motor vehicle use.

Table 6: Environmental Tax Revenues

									€m
Tax	**2009**	**201**	**2011**	**201**	**201**	**201**	**201**	**201**	**201**
Total	**3,847**	**4,10**	**4,204**	**4,18**	**4,44**	**4,64**	**4,94**	**5,07**	**5,1**
Energy taxes	**2,267**	**2,52**	**2,692**	**2,64**	**2,72**	**2,81**	**3,02**	**3,10**	**3,1**
Duty on light hydrocarbon oil products	1,064	993	991	911	854	810	771	725	678
Duty on other hydrocarbon oil products	1,106	1,10	1,128	1,12	1,18	1,23	1,35	1,45	1,5
Electricity tax	2	7	7	7	6	6	4	5	4
National Oil Reserves Agency levy	93	140	130	123	124	121	130	132	132
Carbon tax	2	235	301	363	387	386	419	434	429
Carbon credits	-1	0	-4	14	17	12	20	15	11
Public Service Obligation levy	0	39	140	102	151	242	333	342	392
Transport taxes	**1,523**	**1,52**	**1,449**	**1,47**	**1,66**	**1,78**	**1,87**	**1,91**	**1,9**
Vehicle registration tax	373	395	394	384	459	572	702	814	850
Air travel tax	92	103	44	34	34	11	0	0	0
National Car Test (NCT) Levy	0	0	0	0	19	21	26	24	24
Motor tax (business)	264	256	253	264	284	290	281	263	255
Motor tax (households)	787	761	749	781	853	869	843	789	766
Vehicle and driving licence expenses	6	7	9	10	13	20	20	20	20
Pollution and Resource taxes	**57**	**61**	**63**	**67**	**59**	**48**	**47**	**58**	**51**
Plastic bag levy	23	17	16	14	15	13	12	10	17
Landfill levy	32	43	46	52	43	34	34	47	32
Fisheries protection	1	1	1	1	1	1	1	1	1

Source: CSO (2019)

While environmental taxes are often levied to alter behaviour for attempted environmental benefits, other publicly-funded supports have a potentially negative impact on the environment. For example, agricultural subsidies can yield nutrient pollution and biodiversity loss. The CSO has prepared estimates from 2012 to 2016 detailing the extent of such potentially environmentally damaging subsidies on a voluntary basis (Table 7). A subsidy is classified as potentially environmentally damaging if *"it is likely to incentivise behaviour that could be damaging to the environment irrespective of its importance for other policy purposes"* (CSO, 2019). The CSO has classified subsidies into four categories: fossil fuel supports; agriculture and food supports; transport supports; and fishing and aquaculture supports.

In 2016, total potentially environmentally damaging subsidies were estimated at €4.1 billion; €2.5 billion of which supported fossil fuel activities. The majority of direct fossil fuel supports are delivered through the fuel and electricity allowances to households as well as support for the burning of peat for electricity generation through a Public Service Obligation (PSO) levy on all electricity consumers. The official rationale for the PSO levy to subsidise peat-fired electricity is on the grounds of energy security (CRU, 2018). Political concerns regarding employment in the Irish midlands where the majority of peat production has historically taken place means socio-economic policy may also be an implicit factor (Honohan 1997; Manning & McDowell, 1984). The support for peat burning has been much criticized by Irish economists (Honahan, 1997; Fitzgerald et al. 2005; Tuohy et al. 2009; Bullock & Collier 2011; O'Mahoney et al., 2013; Gorecki et al 2011; Farrell & Lyons 2015; Lynch, 2017). A key concern is the decision that peat plants run at full capacity when many have argued that security need not be sacrificed by running at a much lower capacity. Furthermore, other policy developments have greatly enhanced energy security such as greater electricity interconnection, which may be sufficient in and of themselves to alleviate the earlier security concerns (Gorecki et al. 2011). The largest single support for fossil fuels is through revenue forgone.

Table 7: Potentially Environmentally Damaging Subsidies by Activity

					€m
Supports	**2012**	**2013**	**2014**	**2015**	**2016**
Total Supports	**4186**	**4111**	**4207**	**4035**	**4093**
Fossil Fuel	2260	2315	2380	2479	2505
Agriculture and Food	1904	1760	1739	1462	1490
Transport	10	15	60	65	82
Fishing and Aquaculture	12	22	27	29	16
Direct Supports	**2168**	**2064**	**2109**	**1702**	**1799**
Fossil Fuel	558	562	628	561	534
Agriculture and Food	1601	1492	1470	1130	1255
Transport	7	8	8	8	8
Fishing and Aquaculture	3	3	3	4	3
Indirect Supports	**2018**	**2047**	**2098**	**2332**	**2293**
Fossil Fuel	1703	1753	1752	1917	1971
Agriculture and Food	304	268	269	332	235
Transport	3	7	52	58	74
Fishing and Aquaculture	9	20	24	25	13

Source: CSO (2019)

It is important to note that many of the potentially environmentally damaging subsidies often target various important social goals, for example, the fuel allowance is aimed at tackling fuel poverty. Environmentally friendly alternatives to household fuel allowances include supports for improved insulation. Subsidies intended to support activities that protect the environment or reduce the use and extraction of natural resources are termed "environmental transfers". The classifications of environmental transfers used by the CSO are based on the UN SEEA. In 2017, environmental transfers reached their peak at €685m of which 31% supported renewable energy production, 26% wastewater management, 23% biodiversity protection and 9% heat and energy-saving measures (Table 8). Other activities, such as waste management and climate protection accounted for the remaining 10%.

Table 8: Environmental Transfers: Source: CSO (2019)

					€m
Environmental Transfers	**2012**	**2013**	**2014**	**2015**	**2016**
Subsidies on production	290	264	251	225	336
Social transfers in kind	24	32	63	57	53
Other current transfers within government	25	25	22	17	12
Current international cooperation	0.3	0.3	0.3	0.3	0.3
Investment grants	237	194	209	233	266
Other capital transfers	0.3	0.4	0.4	0.4	0.4
Tax rate relief	0.4	0.2	0.3	0.6	0.9
Accelerated depreciation allowances	0.1	0.1	0.1	0.1	0.1

Total	**587**	**524**	**556**	**546**	**685**

Fig. 3 illustrates the large disparity between potentially damaging environmental subsidies, an average of €4.1bn annually from 2012-2016, and environmental transfers of €0.6bn over the same period.

<Figure 3 >

Fig. 3: Environmental revenues, subsidies and transfers

3.3 Critique and Recommendations

For prudent environmental policy, it is vital to have appropriate measures to inform us about the sustainability of our economic development. After all, it was the recognition that the SNA fails to appropriately account for the environment that prompted the initial development of natural capital accounting (Ahmad et al., 1989). The implementation of the SEEA CF represents an important first step in assessing the state of Ireland's natural assets and their relationship with economic activity. Air emissions accounts are central to the development of national climate change mitigation policy and can be used to evaluate the effectiveness of measures taken to achieve policy goals. Material Flow Accounts detail the economy's dependence on materials and combined with macroeconomic data offer us an indication of resource productivity. Further developments with regard to full and extended historical accounts for flows such as water and waste would be valuable additions. The systematic recording of environmental expenditures is another important development and highlights the large mismatch between potentially environmentally damaging subsidies and environmental transfers.

Ireland has closely followed the EU regulations and as such has focused on physical flow and environmental expenditure accounts. Environmental asset accounts are missing and it is the asset accounts that are more relevant for sustainability assessment. Only by ensuring the health of the asset can we expect continued flows. The failure to develop asset accounts is particularly disappointing given the MAES project conducted by the NPWS was completed in 2016 and it appears little progress has been made subsequently to develop and integrate a natural capital asset register within national accounting systems which is a target within the National Biodiversity Action Plan, target 1.1.10 (DCHG, 2017). The development of environmental asset accounts in both physical and monetary terms would be highly valuable. Rough environmental asset accounts for Ireland, in monetary terms, have been compiled by the World Bank for the years 1995, 2000, 2005, 2010 and 2014 with Ireland's total aggregate natural capital (mineral and energy resources, forestry and agricultural land) valued at €67bn in 2014 (World Bank, 2018). The future construction of ecosystem accounts represents a promising area for future research, as is the construction of detailed land maps. The lack of accurate data on ecosystems and land cover could prevent the accurate prediction and prevention of pollution, flooding and other climate effects.

4. Environmentally Adjusted Macro-Aggregate: Irish "Genuine Savings" 1990-2016.[10]

Economic theory suggests the sustainability of Ireland's development path, from the perspective of the capital approach, can be examined by undertaking an empirical exercise in natural capital accounting. GS is an environmentally adjusted macro-aggregate that measures, in monetary terms, the annual change (net investments) in the value of the economy's comprehensive wealth. GS involves adjusting the SNA aggregates to reflect changes in the stocks of human, physical and natural capital. Declining wealth (negative GS) signals unsustainable development indicating that the current generation is consuming capital assets and diminishing future welfare opportunities.

A tight connection among the fundamental economic concepts of "wealth", "income", "sustainability", and "accounting" provides a solid theoretical grounding for the GS indicator (Weitzman, 2016). The capital approach conceptualises a sustainable development path as one that is capable of providing the opportunity for non-declining welfare through time. Dasgupta and Mäler (2000) demonstrate, theoretically, that a development path where the correctly valued comprehensive wealth of the economy is maintained through time also maintains the welfare opportunities for each subsequent generation. Wealth must be comprehensive in the sense that it contains all capital assets that individuals obtain well-being from, either directly or indirectly, thus must be broadly defined to comprise not only physical (machines and infrastructure), but human capital (education and skills), natural capital (clean air, natural resources) and social/institutional capital (culture and trust).

[10] This section is largely based on McGrath, L., Hynes, S., & McHale, J., 2019. Augmenting the World Bank's estimates: Ireland's Genuine Savings through boom and bust. *Ecological Economics*, 165.

4.1 Methodology

GS has gained international recognition through the publications of the World Bank who construct estimates for most countries (World Bank, 2006, 2011, & 2018). The World Bank calculates GS by making "green" adjustments to Gross National Savings (GNS), as reported in the conventional System of National Accounts (SNA). GNS represent the traditional measure of national savings (gross national income less total consumption, plus net transfers). Another standard item in the SNA is the consumption of fixed capital (CFC) and this is an estimate of the depreciation of physical capital. Subtracting CFC from GNS equates Net National Savings (NNS) and signifies net investments of physical capital. The depletion of the natural capital stock includes the depletion of subsoil assets (oil, natural gas, and coal, bauxite, copper, gold, iron ore, lead, nickel, phosphate, silver, tin, and zinc), forestry depletion and a limited coverage of pollution damages (carbon dioxide and particulate matter). The valuation of the subsoil assets and forestry rely on a net present value approach using market prices and estimated costs of extraction. This valuation technique is unable to capture non-marketed ecosystem services. The pollution damages are valued based on marginal damage cost estimates that reflect future damages but it should be noted that the GHG (carbon dioxide) and non-GHG (particulate matter) emissions are accounted for differently. Non GHGs are estimated as damages to country X from emissions in country X. For the GHGs damages the polluter pays principle is employed where country X is notionally charged for its contribution to global damages not damages to country X. Finally, an estimate of human capital accumulation as net education expenditures is added.[11] GS is then generally reported as a savings rate by dividing savings by Gross National Income (GNI).

$$\begin{aligned} \textit{Genuine Savings} \; = \; & \textit{Gross National Savings} \\ & \textit{less depletion of physical capital} \\ & \textit{less depletion of natural capital} \\ & \textit{plus additional human capital} \end{aligned}$$

The World Bank's estimates show persistently positive and high savings rates for Ireland (Fig. 4) and other developed economies but a large literature critically appraising the World Bank's methods calls for methodological improvements (Ferreira & Vincent 2005; Pillarisetti 2005; Dietz & Neumayer 2006; Atkinson & Hamilton 2007; Neumayer 2013; Boos 2015; Hanley et al. 2015). The World Bank's goal is to provide comparable and consistent dataset across a large heterogeneous sample of countries and results in an inevitable trade-off between the capture of country-specific characteristics and the application of a common methodology. One key concern

[11] For detailed methodology see World Bank (2018). For a formal derivation of the GS model see Hamilton and Clemens (1999).

is that developed economies might be less sustainable than the World Bank figures suggest owing to important omissions such as local air pollution.[12]

McGrath et al., (2019) present augmented estimates of Irish GS by constructing a time-series predominantly from national data sources, including the most comprehensive coverage of air pollution in the literature, by accounting for other important characteristics omitted by the World Bank (peat depletion, forestry growth, and agricultural land value) and by examining issues such as technological advancement, transboundary pollution, climate change and population growth. The authors present three headline GS estimates for Ireland (GS1, GS2 & GS3) which vary based only on different assumptions regarding pollution damages. GS1 takes the upper bound estimates of environmental damages and GS3 takes the lower bound.[13] One may interpret GS1 as the most pessimistic estimate.

4.2 Application

Fig. 4 presents the range of GS estimates as well as the conventional savings measure Gross National Savings (GNS). It is apparent that neither "Celtic tiger" growth, from the mid-1990s to the mid-2000s, nor the economic downturn from 2008-2010, appear to coincide with unsustainable development. Pre-tiger, the Irish economy signals unsustainability through low or negative savings from 1990-1995, in the GS1 measure (taking the upper-bound estimates of environmental damages). There is, in fact, some evidence to suggest the economy transitioned away from an unsustainable path during the boom period.

<Figure 4 >

Fig. 4: Gross National Savings and the range of Genuine Savings estimates 1990-2016

Fig. 5 illustrates the components of the GS1 measure, the results are driven by damages from local air pollution (up to 18% of GNI), during the early 90s. During the economic boom period, rapid economic growth translated into strong net physical capital investment while human capital accumulation remained steady. As the boom period commenced, total environmental damages began to decline considerably. These positive factors resulted in substantial increases in GS and

[12] Another concern is that of "virtual sustainability" where a net exporter of fossil fuels will have much lower depletion estimates than a net-exporter (Atkinson et al., 2012). The depletion estimates are accounted for using a production-based methodology, as the conventional thought is that the liability arising from the (negative) change in the resource stock arising from depletion should be attributed to the accounts of the producing country. The issue with consumption based accounting that is acknowledged by Atkinson et al. 2012 is that measuring resource consumption does not translate directly into an obvious rule about how much a resource-consuming economy should save to satisfy sustainable development.

[13] See McGrath et al., (2019) for a detailed methodology.

continued until the collapse in net physical capital accumulation during the global recession. Savings rates rose considerably following the economic recovery and reached new peaks in each scenario by the end of the observed period.

<Figure 5 >

Fig. 5: Components of GS1

All three GS measures are consistently and considerably lower than the World Bank's estimates for Ireland, particularly during the early 1990s. Fig. 6 illustrates the large disparity between GS1 and the World Bank. GS1 is 20 percentage points below the World Bank estimate during the early 1990s. From 2014, GS1 yields similar results to the World Bank. This is largely explained through the remarkable decline in the additional environmental damages contained in the GS1 measure. The stark decline in environmental damages also explains the convergence of the three augmented GS measures in Fig.4.

<Figure 6 >

Fig. 6: GS1 in comparison to the World Bank

Fig. 7 illustrates the sharp reduction in total environmental damages across all three GS measures. In GS1 damages fell from 18% GNI (€9.5bn in 2000 prices) to 3% (€3.9bn) over the observed period, in GS2 damages fell from 7% GNI to 1% and in GS3 damages fell from 3% GNI to 0.4%.

<Figure 7 >

Fig 7: Total environmental damages across the GS measures

There is not only a sharp decline in damages but also a sharp decline in emissions, only CO_2 and NH_3 emissions are higher in 2016 than in 1990 (Table 9). Most non-GHG emissions and economic growth have strongly decoupled from the onset of the Celtic Tiger but GHGs remain coupled.

Table 9: Emissions from 1990-2016

Pollutants*	Emissions 1990	Emissions 2016	% Change in Emissions 1990-2016
CO_2	32878 kt	39928 kt	+21%

PM2.5	35 kt	15 kt	-58%%
SO_2	184 kt	14 kt	-93%
NOx	175 kt	107 kt	-39%
NH_3	110 kt	117 Kt	+6%
CO	350 kt	106 kt	-70%
NMVOC	146 kt	108 kt	-26%
CH_4	595 kt	548 kt	-8%

*CO_2 =carbon dioxide; PM2.5 = particulate matter, SO_2 = sulphur dioxide, NOx = nitrogen oxides, NH_3 = ammonia, CO = carbon monoxide, NMVOC =non-metallic volatile organic compounds & CH_4 = methane.

SO_2; the largest component (over half of the total damages) for almost two decades, has been the key driver of the total damage costs (Fig. 8). SO_2 emissions have fallen 93% from 1990 due to a mixture of market-based incentives, structural changes and environmental policies (EPA, 2018). Just CO_2 and NH_3 emissions are higher in 2016 than in 1990 and are both heavily influenced by agriculture. CO_2 rose 24% down from a 2005 peak of 47% above 1990 levels. NH_3 emissions exceeded the NEC emission ceiling in 2016 for the first time and reductions may be difficult given ambitious government targets in Food Wise 2025 (EPA, 2018).[14]

<Figure 8 >

Fig. 8: Breakdown of Pollution Damages: GS1

These findings are significant in a number of ways. Observations of negative savings rates for a developed economy, under any scenario, are extremely rare in the GS literature. These rare observations have generally been a result of either major economic events such as the World Wars (Blum et al., 2017) or a result of volatility in resource prices (Hanley et al., 1999). In contrast, environmental damages drive the Irish results and highlight the importance of broader coverage of pollutant damages within GS estimates. The results also suggest rapid economic development *and* rapid declines in environmental damages can occur concurrently and on the transition away from an unsustainable development path. In contrast, the GS literature has generally shown that rising physical capital investments have merely more than compensated for an increase in total environmental damages on the transition away from an unsustainable path (e.g. Lindmark and Acar, 2013).

[14] Food Wise 2025 identifies ambitious and challenging growth in the agriculture sector including an 85% increase in exports to €19 billion; 70% increase in value added to €13 billion 65% increase in primary production to €10 billion and The creation of 23,000 additional jobs all along the supply chain from producer level to high end value added product development.

There are often calls for a curtailment of economic growth to *"save the environment,"* the results reinforce the suggestion that what matters is not economic growth per se, but the manner in which that economic growth is secured. In the Irish case, it appears that total pollution damages were falling substantially while rapid levels of economic growth were secured. The results demonstrate the potentially large benefits attainable from continued pollution reductions and provide a reminder that a system of regulations prioritising one particular problem such as carbon dioxide emissions at the expense of others such as damaging local air pollutants may result in misguided public policy. The measurement of genuine savings provides a valuable framework for aggregate assessments where such trade-offs are involved. In terms of sustainability assessments, governments and statistical agencies should be cognisant of the theoretical literature suggesting changes in the economy's comprehensive wealth should be the focus of any economic component. GS provides a valuable aggregate indicator that can be highly informative for an initial sustainability assessment and provide a useful guide to where further analysis is required.

4.3 Critique and Recommendations

In terms of policy use, it is important to note the practical limitations of real-world GS calculations and the one-sided nature of the GS indicator. In particular, the valuation techniques fail to capture the non-marketed value of natural capital and this is likely to be a significant omission in relation to the explicit estimates of peat depletion. Peatlands possess a high capacity for carbon storage and provide a multitude of other non-marketed ecosystem service benefits. The lost ecosystem service benefits and other non-market values will not feature in the depreciation estimate; however, damages from the burning of peat will be implicitly captured implicitly in the estimates of pollution damage. Given these limitations, it is important to stress what GS theory tells us, that is if savings are negative the theory implies that the economy is on an unsustainable path. However, the opposite is not necessarily true. Positive savings imply a welfare improvement, which has been demonstrated empirically (Greasley et al, 2014; Hanley et al., 1999), but cannot guarantee a sustainable development path (Pezzey, 2004). For policymakers, low or negative savings indicate a strong warning but a finding of positive rates cannot be taken as a clean bill of health, further analysis is required.

The discussion of sustainable development contained in this section surrounds the capital approach and that GS is generally considered an indicator of weak sustainability. Many environmentalists reject the notion of weak sustainability however it should be noted that weak and strong sustainability are *both* non-falsifiable as they *both* rely on assumptions about the unknown future (Neumayer, 2013). Weak sustainability indicators can still provide valuable information even if one is a proponent of stronger form as the achievement of weak sustainability might be conceptualised as a first step towards the achievement of strong sustainability or by recognising that an economy failing a weak sustainability test is, in all likelihood, going to fail a strong sustainability test. The key issues relate to the substitutability assumption and the coverage and valuation of the capital assets (Ferreira & Vincent 2005; Pillarisetti 2005; Dietz & Neumayer 2006; Atkinson & Hamilton 2007; Goosens et al., 2007; Stiglitz et al., 2009; Neumayer 2013; Hanley et al. 2015). Much of the debate that surrounds the validity of the substitution assumption is confused and partly stems from differing domains marginal and total substitution. Given a domain of total substitution, strong sustainability is self-evidently true, as the total substitution of natural capital would lead to the cessation of all life. In economics, substitution is at the margin and is not costless nor constant. Given the domain of marginal substitution, the issue becomes a practical rather than a theoretical problem. In theory, threshold effects could be captured with perfect foresight and the correct accounting prices. In practice, the identification and monitoring of critical natural assets in physical terms seems sensible. [15]

We argue that estimates of GS, a leading indicator of the capital approach be developed for inclusion within the economic component of any sustainable development indicator set. Many of the contentious assumptions required to compute the GS indicator are already contained in the updated public spending code (IGEES, 2019), these include a decision on test discount rates and the marginal social costs of both GHG and non-GHG pollutants. McGrath et al. (2020) present GS estimates using guidance from the public spending code. Furthermore, it seems plausible that the output from the various natural capital accounting projects being undertaken across Ireland may be integrated with GS measures in the near future.

5. Other Natural Capital Accounting projects

In this section, we discuss various projects that have been undertaken or have commenced. Table 10 suggests how the data that these projects can generate may be incorporated into natural capital accounts.

[15] Critical natural capital is defined as an asset within the stock of natural capital stock that must be maintained to preserve welfare and is therefore non-substitutable. Pearce et al., (1989) view the assimilative capacity of the environment as well as a certain stock of living natural resources that function as basic life-support systems as “critical”.

5.1 Mapping and Assessment of Ecosystems and their Services -MAES

The EU Biodiversity Strategy outlines a number of targets and actions to curtail biodiversity loss. Target 2, Action 5 calls on the Member States to map and asses the state of ecosystems and the services they provide within national boundaries. Member States must also asses the economic value of ecosystem services and integrate these values within national accounting systems. The National Parks and Wildlife Service (NPWS) completed a short project for a National Ecosystem and Ecosystem Services mapping pilot for a suite of prioritised services based on available data in 2016. The project modelled selected ecosystem services to create maps of; land temporarily storing water, areas of land promoting good water quality, vegetation carbon, soil carbon, terrestrial food, terrestrial biodiversity, marine areas that provide food, marine carbon, marine biodiversity. The data generated from the MAES project is expected to be used to value ecosystems and their services (DCHG, 2019).

5.2 Irish Natural Capital Accounting for Sustainable Environment (INCASE)

INCASE is an Environmental Protection Agency funded, transdisciplinary project, with the aim of developing natural capital accounting systems in Ireland. The project team is based at Trinity College Dublin, University College Dublin, University of Limerick, National University of Ireland Galway and the Irish Forum on Natural Capital. The team will review approaches and data sources to develop ecosystem and environmental flow accounts for Irish catchments.

5.3 National Land Cover Data Initiative

The National Land Cover Data Initiative was established following the recommendations of a report on the potential value of a national land cover database that was commissioned by the Department of Culture Heritage and the Gaeltacht and the Heritage Council (DCHG). The initiative aims to collate land cover data that is being collected by various agencies and projects. Previously only low-resolution land cover data was available from the European CORINE database, but this data is now being combined with finer level national land use/land cover (LULC) datasets available from other sources such as Ordnance Survey Ireland (OSi) (DCHG, 2019).

5.4 Natural Capital Assessment in Northern Ireland: Urban Study

Natural Capital Solutions were commissioned by Northern Ireland Environment Link (NIEL) to undertake a natural capital assessment of two urban sites in the Belfast area. The report presents a natural capital assessment of Bog Meadows and Minnowburn. The assessment aims to identify and asses existing natural capital assets through an asset register and flow of services in both physical and monetary accounts (Coldwell et al., 2018).

5.5 Marine Ecosystem Service Benefit Valuation

Elsewhere, the Socio-Economic Marine Research Unit, NUI Galway have also been pursuing a programme of research funded through the Irish Marine Institute and the Irish Environmental Protection Agency (EPA) that has been estimating the value of marine ecosystem service benefits to Irish society (Norton et al., 2018 and Norton and Hynes, 2018). The main aims of this work has been to provide a profile of the marine ecosystem services derived from Ireland's coastal, marine and estuarine natural resources, provide estimates of the value to society of these marine ecosystem services and finally to identify knowledge gaps that continue to exist in the valuation of marine ecosystem services. The Norton et al. (2018) report notes that factoring marine ecosystem service values into ocean economy account frameworks may help to ensure a sustainable "blue economy" for Ireland by making sure that growth in the ocean economy does not exceed the carrying capacity of the marine environment.

Table 10: Potential Outputs from Various Natural Capital Accounting Projects.

Project	Physical Flow	Environmental Expenditure	Environmental Asset	Environmentally Adjusted Macro-Aggregate	Ecosystem Accounts
Mapping and Assessment of Ecosystems and their Services – MAES			**X**	**?**	**X**
Irish Natural Capital Accounting for Sustainable Environment (INCASE)	**X**		**X**	**?**	**X**
National Land Cover Data Initiative			**X**		
Natural Capital Assessment in Northern Ireland: Urban Study	**X**		**X**		**X**
SEMRU: Marine Ecosystem Benefit Valuation	**X**		**X**		**X**

6. Concluding remarks

Natural capital accounts permit the integration of our natural assets within economic and political decision-making, can improve natural resource governance and are an important component within complements to Gross Domestic Product (GDP). There have been many positive developments regarding natural capital accounting in Ireland but we still lag behind natural capital pioneers such as Norway, the Netherlands and the UK (e.g. CBS, 2018; ONS, 2019). The CSO's implementation of the SEEA CF through EU regulations and the development of further accounts on a voluntary basis is a major positive development. Air emissions accounts are central to the development of national climate change mitigation policy and can be used to evaluate the effectiveness of measures taken to achieve policy goals. Material Flow Accounts offer measurement of the economy's dependence on material inputs. The systematic recording of environmental expenditures highlights the large mismatch between potentially environmentally damaging subsidies and environmental transfers. Further developments with regard to full and extended historical physical flow accounts for resources such as water and waste would be valuable additions. Ireland has at present, closely followed the EU regulations and as such have focused on physical flow and environmental expenditure accounts. Environmental asset accounts are more relevant for any type of sustainability assessment and thus work in this area is desirable.

It is clear that much work remains to be done in order for an adequate sustainability assessment of Irish economic development. It is obvious that no single indicator can provide an all-encompassing answer to questions surrounding sustainable development. Natural capital accounts are important regardless of what concept of sustainability is preferred. Given the focus of the SEEA relates to the integration of environmental and economic data within macroeconomic accounts the framework is best suited to the capital approach. The capital approach encompasses two interpretations of the conditions required to achieve sustainability (non-declining wealth), both strong and weak sustainability. Advocates of strong sustainability will be inclined towards ecological indicators that assume non-substitution between natural and other capital forms. Advocates of weak sustainability stress substitution possibilities and technological optimism such that aggregative monetary indicators are more appealing. We argue that estimates of GS, a leading indicator of the capital approach be developed for inclusion within the economic component of any sustainable development indicator set. It seems plausible that the output from the various natural capital accounting projects being undertaken across Ireland may be integrated with GS measures in the near future. If one advocates strong sustainability, *additional* rather than alternative indicators are required. In theory a perfect measure of GS would incorporate ecological thresholds through the relevant accounting prices but this may never be feasible in practice. Thus the identification and measurement of stocks of critical natural capital in physical terms, may be required.

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Appendix

A.1 Genuine Savings and Intergenerational Well-being – Key Theoretical Results

The comprehensive wealth of an economy, W, at time t can be represented by the sum of its assets - the stocks of human-made (K), human (H) and natural capital (S), each evaluated at their correct shadow prices (k_t, μ_t, λ_t) reflecting their marginal contributions to utility (Dasgupta and Mäler, 2000; Arrow et al., 2012).

$$W_t = k_t K_t + \mu_t H_t + \lambda_t S_t \qquad (1)$$

With constant population, stationary exogenous total factor productivity and import/export prices the change in wealth *(GS)* equals the change in well-being (*V),* expressed using a Ramsey-Koopmans formulation $V_t = \int_0^\infty U(C_\tau) e^{-\delta(\tau - t)}\, d\tau$ (Dasgupta, 2009).

$$\frac{dV_t}{dt} = GS_t = \frac{k_t dK_t}{dt} + \frac{\mu_t dH_t}{dt} + \frac{\lambda_t dS_t}{dt} \qquad (2)$$

From (2) GS have the same corresponding sign as the change in intergenerational well-being.

Figures 1 – 8

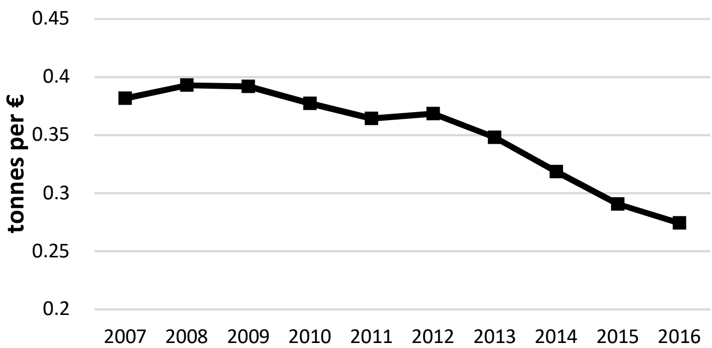

Fig. 1: Emissions Intensity of Greenhouse Gases 2007-2016

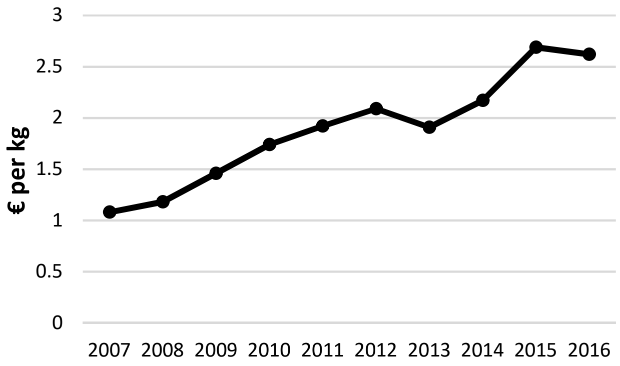

Fig. 2: Resource Productivity (GDP/DMC) 2007-2016

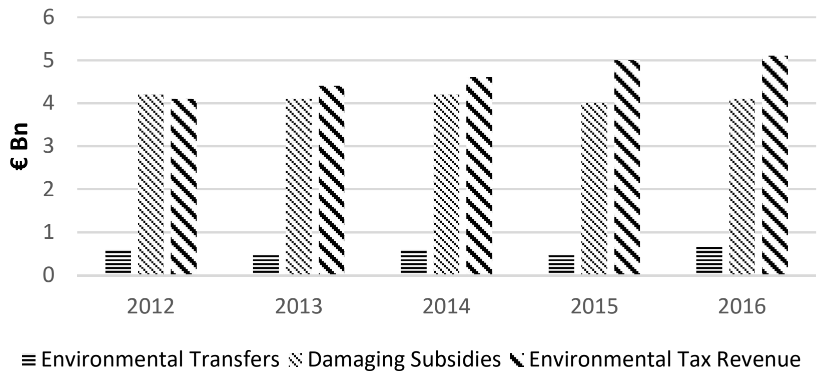

Fig. 3: Environmental revenues, subsidies and transfers

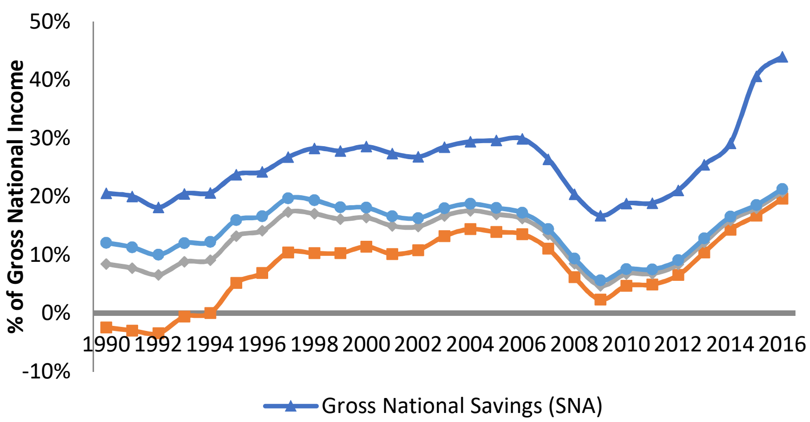

Fig. 4: Gross National Savings and the range of Genuine Savings estimates 1990-2016

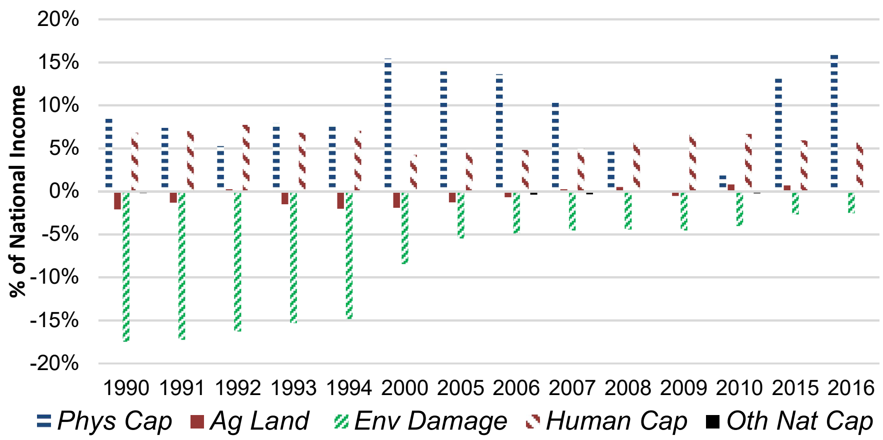

Fig. 5: Components of GS1

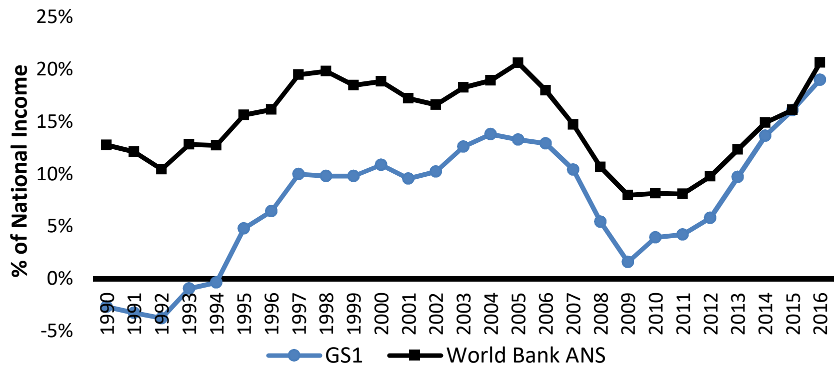

Fig. 6: GS1 in comparison to the World Bank

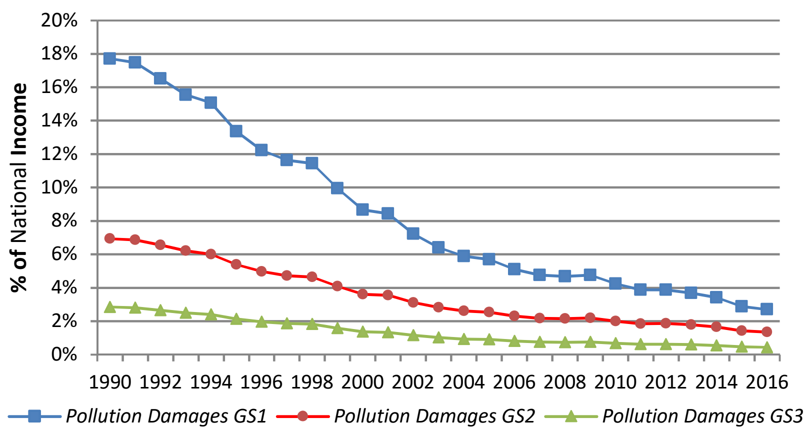

Fig 7: Total environmental damages across the GS measures

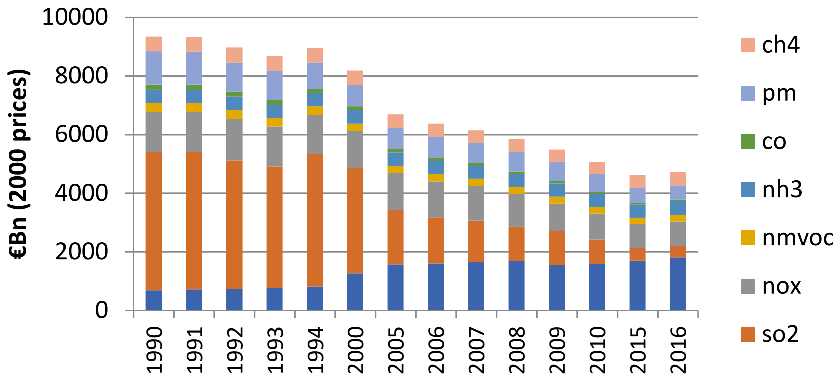

Fig. 8: Breakdown of Pollution Damages: GS1

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