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Accounting for Produced Environmental Assets

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Abstract

This paper explores the extent to which existing national accounting guidelines – the System of National Accounts (SNA) 2008 and European System of Accounts (ESA) 2010 – already include produced environmental assets in their theoretical scope. Three produced capital classes potentially relate to the environment: land improvements, cultivated biological resources, and terminal costs. The definitions of these capital classes in existing guidelines allow for a large amount of expenditure to be treated as gross fixed capital formation, but current practice is much more limited. In other words, environmental investment may be going unmeasured despite being theoretically in scope for national accounts. Similarly, both the stock of produced environmental assets and the depreciation of those environmental assets may also be going unmeasured. As such, current estimates of measured gross fixed capital formation, measured produced capital stock, and measured consumption of fixed capital could all be much lower than SNA 2008 and ESA 2010 theoretically allow for. This paper concludes with three case studies, one for each produced capital class.

Keywords: environmental assets, non-produced natural resources, green investment, economic measurement, national income accounting, capital

JEL codes: E01, E22, Q00

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1. Introduction

There is growing interest in understanding how national accounts can better reflect environmental issues, including natural capital and the cost of environmental damage caused by economic activity. Indeed, the forthcoming revision of the national accounting guidelines embodied in the System of National Accounts (expected in 2025) is considering environmental issues as one of its key topics. However, some environmental issues are already captured in the existing national accounting guidelines, at least in theory.

This paper considers a particular type of environmental issue in the national accounts: produced assets that either improve or damage the environment. These produced assets are already conceptually included in the national accounts under current guidelines which are laid out in the System of National Accounts 2008 (SNA 2008) and/or European System of Accounts 2010 (ESA 2010). That is, components of gross fixed capital formation (GFCF) can be thought of as environmental improvement. Conversely, components of consumption of fixed capital (CFC) can be thought of as environmental damage.

The published national accounts already include some produced assets that either improve or damage the environment. For example, sewage processing plants which remediate biological pollution are already included in the measured structures stock and trucks which emit air pollution are already included in the measured equipment stock. Because assets like these are already captured in the accounts, they will not be discussed further in this paper.

Instead, this paper focuses on three produced fixed asset classes as defined in SNA 2008 and ESA 2010: land improvements, cultivated biological resources, and terminal costs. The paper shows that the definitions of these capital classes in existing guidelines allow for a large amount of expenditure to be treated as investment, but that current practice is much more limited. The aim of this paper is to highlight the potential for greater attention on these usually overlooked asset classes. The paper then presents three preliminary case studies of environment assets that are not currently captured in the accounts and that could be within current definitions. Much more research is needed before the assets in the case studies or other environmental assets could be captured in the published national accounts.

Since SNA 2008 clearly states that externalities are not in scope of the core accounts (sections 3.92-3.95), this paper excludes all externalities associated with environmental assets from its analysis. Due to this exclusion, the assets studied provide capital services locally to their owners, rather than globally. Some key environmental improvements, such as carbon sequestration, are excluded since the value of these assets is principally in their global impact. Conversely, some key environmental damages, such as extinction of endangered species, are excluded since the cost of these assets is principally in their global impact. In other words, assets whose environmental impact is diffuse and global are excluded from analysis. A comprehensive measure of environmental issues would include externalities, and would thus go beyond the scope of current national accounting guidelines and of this paper.

The paper proceeds as follows. Section 2 briefly reviews the literature on environmental economic accounting and then describes in more detail the conceptual framework and scope of the environmental assets considered in this paper. Sections 3-5 describe in detail the theoretical and practical measurement of land improvements, cultivated biological resources, and terminal costs, respectively. Section 6 presents three preliminary measurement case studies, one for each asset class. Section 7 concludes.

2. Literature and Conceptual Framework

2.1 National Accounting Guidelines

The key national accounting guidelines are contained in the SNA 2008 and the ESA 2010. At the time this paper was written in the summer of 2024, SNA 2008 was the latest official national accounting guidelines.[1] SNA 2008 is followed, to a greater or lesser extent, by most countries globally. Member states of the European Union must compile national accounts in accordance with the guidelines for implementing SNA 2008 that are laid out in ESA 2010. Alongside SNA 2008 and ESA 2010, supplementary guidelines that document particular concepts or aspects of the accounts have been produced. One that is of relevance to this paper is the OECD manual 'Measuring Capital' (OECD, 2009). Another is the Eurostat-OECD compilation guide on land estimation (OECD and Eurostat, 2015), which includes a section on land improvements. This paper refers to the two key national accounting guidelines and the supplementary guidelines throughout.

This paper focuses on measurement practice in two countries: the US and the UK. The US does not follow SNA 2008 completely, though it does to a large extent. The UK, since its exit from the European Union, is no longer required to follow ESA 2010. However, the Office of National Statistics (ONS) has confirmed that it follows ESA 2010 on a voluntary basis for now. These measurement practices help international comparability, which users of national accounting data demand. Therefore, the measurement practices of the US and the UK are likely to be reasonable proxies for the measurement practices of other developed countries.

2.2 Environmental Accounting Guidelines

The main document on environmental accounting is the System of Environmental Economic Accounting (SEEA). This is complementary to SNA 2008, using some of the same structures and classifications, but providing greater detail and information on environmental assets, natural capital and ecosystem assets. However, SEEA sometimes uses different terms than SNA 2008 so that the similarities between the two documents are less apparent. SEEA is split into two parts:

1. SEEA Central Framework (SEEA CF), adopted in 2012 – this looks at environmental assets, such as water resources, energy resources, forests, and fisheries. It also looks at their economic uses and associated emissions.

2. SEEA Ecosystem Accounting (SEEA EA), adopted in 2021 – this considers ecosystems, which are combinations or interactions of environmental assets, and the ecosystem services derived from environmental assets.

SEEA covers data in physical and monetary units, with those in monetary units largely overlapping with SNA assets. SEEA and SNA recognise largely the same environmental assets, though SEEA identifies soil separately from land whereas SNA treats land and soil together (SNA 2008, 10.175, p.214). But while SNA only recognizes natural resources as

[1] This follows previous versions in 1993, 1968, 1964, 1960 and 1953. A 1947 report of the United Nationals Statistical Commission is arguably the origins of the SNA.

environmental assets when there is effective ownership and economic benefits accruing to the owner from the asset (SNA 2008, 10.168, p.212), SEEA includes all environmental assets in the country's territory.

This paper provides discussion of the SNA definitions of three produced asset classes and critiques current measurement practice. It is therefore largely agnostic to the scope of environmental assets captured in SNA and SEEA. Rather, this paper argues that SNA definitions, if interpreted fully and consistently, give scope to treat many more environmental assets as produced assets (and thus more expenditure as investment). This would likely not change the overall valuation of environmental assets in SEEA, since SEEA includes both produced (cultivated) and non-produced (uncultivated) environmental assets. Rather, this would potentially change the share of value attributed to the cultivated aspect of assets. For instance, if SEEA included £100 of land, and the valuation of land improvements increases from £10 to £20 based on a fuller measurement of land improvements (consistent with the SNA definition), then the total value of the land would be unchanged at £100; only the partitioning of that £100 into produced and non-produced would change.

An alternative method to account for the environment is presented in Agarwala and Martin (2022). That paper calculates environmentally adjusted output and productivity measures for the UK, including one measure which adds "unmeasured good output" to gross value added, representing "unmeasured output in the form of environmental protection". They argue that businesses incur costs to protect the environment, but this is not recorded as output or investment – if it were, it would add to gross domestic product (GDP). They estimate this unmeasured environmental protection output by a sum of costs approach and suggest that it is equivalent to around 5% of UK GDP in value terms. This paper complements Agarwala and Martin (2022)'s approach by considering the degree to which "unmeasured output in the form of environmental protection" may actually be an environmental investment that can be captured in national accounts, both in theory and in practice.

2.3 Conceptual Framework

The first concept studied is gross fixed capital formation (GFCF), which is a component of gross capital formation. GFCF covers expenditures on produced fixed assets within the scope of the asset boundary defined by SNA 2008 and ESA 2010. Fixed assets are those which are expected to be used continuously or repeatedly in production and which provide a benefit to their owner for a period of year or more. In short, GFCF is capital investment. It covers investment in both tangible and intangible capital, though the scope of intangible assets included in the national accounting asset boundary is considered narrow by many economists. Thus, products that either provide benefits only once or provide benefits repeatedly over a period of less than a year are not fixed assets and may be treated as inventory, intermediate consumption, or final consumption expenditure depending on the product and user.

The second concept studied is consumption of fixed capital (CFC). CFC covers value losses of produced fixed assets that are within the asset boundary defined by SNA 2008 and ESA 2010. It covers value losses that are the result of physical deterioration or anticipated obsolescence.[2] In short, CFC is capital depreciation. The vast majority of produced fixed

[2] Asset changes that are associated with catastrophes or other unexpected events are tracked as "other changes in the volume of assets" rather than CFC (SNA 2008, section 12.5-12.72).

assets have a non-zero depreciation rate. Accordingly, including a new asset in the national accounts almost always raises measured CFC as well as measured investment.

Tracking environmental GFCF and CFC raises the level of GDP, but the relationship between GDP and environmental quality is not straightforward. This section briefly reviews the national accounting relationships through which environmental assets can change GDP which is measured according to the current guidelines. Readers familiar with national accounting could skip this section.[3]

Expenditures by units in the market sector are normally captured as one transaction or another in national accounts data. When expenditures are captured as intermediate consumption (IC), they are assumed to be implicitly counted in the output of some other unit. In order to avoid double counting, IC is not added to GDP. Some of the additional environmental investment identified in this paper is likely currently captured as IC. Treating this instead as GFCF adds to GDP, since it reclassifies this expenditure as a final use (GFCF) instead of an intermediate use. GDP from the production side increases due to higher GVA (from lower IC and unchanged output); GDP from the expenditure side increases due to higher GFCF; and GDP from the income side increases due to higher gross operating surplus.

Units produce output for sale (market output) but can also produce output to be retained and used by itself, which is output for own final use. Since there is no transaction associated with output for own final use, its value must be imputed by the national accountant and added to the unit's market output to give total output. Some of the additional environmental investment identified in this paper is likely output for own final use of market sector units which currently goes unmeasured. Tracking this as output for own final use will raise GDP, since additional output and GFCF is identified. GDP from the production side increases due to higher GVA (from higher output and unchanged IC); GDP from the expenditure side increases due to higher GFCF; and GDP from the income side increases due to higher gross operating surplus.

Units in the non-market sector – government and non-profit institutions serving households (NPISH) – provide their output for free or sell it at prices which are not economically meaningful. By convention, these units consume their own non-market output in the national accounts. If environmental investment is done by a government or NPISH, but is not currently treated as GFCF, then the environmental investment will be in GDP as final consumption expenditures by governments or NPISHs. In this case, tracking this environmental investment suggests a change in classification from final consumption expenditure to GFCF without any change to total GDP. This is true irrespective of whether the investment arises from IC or unmeasured output for own-final use.

In the case of consumption of fixed capital (CFC), this will only be tracked for produced fixed assets which are identified in the accounts. Where additional produced environmental assets are identified, there will also be additional CFC. Higher CFC of market sector units does not affect GDP directly, though will affect "net" measures (net of CFC), such as net domestic product. It will also affect measures of productivity which use CFC as part of the estimation of capital services.

[3] The results here are equivalent to those for uncapitalised intangible assets, as discussed in Corrado et al. (2005) amongst others.

Non-market output is measured by the costs of production, including CFC. Thus, the CFC associated with government and NPISHs is included in measured non-market output and therefore measured GDP. Therefore, additional produced environmental assets owned by government and NPISHs, which lead to higher CFC, will increase non-market output and GDP by the value of the newly tracked CFC.

In summary, environmental improvement by the market sector raises measured GDP – but the impact of environmental assets on how the government and NPISH sectors are measured is more nuanced and will be discussed in more detail in the case study section.

3. Land Improvements

3.1 Definition of Land Improvements

Land improvements are defined by SNA 2008 as:

"the result of actions that lead to major improvements in the quantity, quality or productivity of land, or prevent its deterioration" (SNA 2008, 10.79, p.204).

ESA 2010 offers some examples of relevant activities:

"Examples include the increase in asset value arising from land clearance, land contouring, creation of wells and watering holes" (ESA 2010, Annex 7.1, p.183).

The Eurostat-OECD compilation guide on land estimation provides clarifications with regards to land improvements. First, land improvements may apply to any type of land, not just agricultural land (p.132, 8.46). Second, the creation of structures in the vicinity of land, which also affect land, such as seawalls, dykes, dams, and major irrigation systems, are to be treated as investment in structures rather than land improvements (p.132, 8.47 and p.134, 8.65). Third, wells and watering holes (as identified in ESA 2010, above) and in exceptional cases structures like dams, dykes, and irrigation systems, are to be included in land improvements *only* if they are "integral to the land and belong to one owner" (p.134, 8.64).

Through a few examples, the Eurostat-OECD guide also identifies some borderline cases. Increases in the value of land because of nearby construction (e.g., of a road to the land, or a nearby irritation system) are treated as "other changes in volume" of land, specifically economic appearance (K.1), rather than land improvements. This follows since the land itself has not been improved, but the value has increased due to a changed economic situation. However, increases in the value of land because of improvements to the land itself (e.g., the construction of watering holes on the land) are treated as investment in land improvements. If this land was not within the asset boundary previously, for instance if it was unowned and unused, then a land improvement which enables the land to be in the asset boundary has additionally led to the economic appearance of land as a non-produced natural resource.[4]

SNA 2008 suggests that land improvements include "site clearance, preparation for the erection of buildings or planting of crops" (p.264, 13.46). However, the Eurostat-OECD guide clarifies that these costs are usually included in the value of the associated dwelling, building or structure, and should therefore not be considered as land improvements. These

[4] In practice, natural resources with significant market value are extremely likely to be owned by someone. Hence, the implied market value of the previously unowned natural resource is likely minimal.

costs should only be treated as land improvements "if they would, eventually in the future, facilitate the erection of buildings on the land" (p.134, 8.62) which we interpret to mean that the costs are incurred pre-emptively, rather than as part of a construction project which includes the construction of buildings or structures.

3.2 Recommended Accounting Treatment of Land Improvements

Land improvements are a fixed asset in SNA 2008 and are part of the broader asset category "other buildings and structures" (AN.112). Land improvements are separate from the land itself, which is a non-produced asset (natural resources). The non-produced natural resource can be thought of as the land before improvements, and any improvements are a produced asset. In practice, however, this can be hard to measure. Transactions in land, and valuations of land, will typically be for the combination of the (non-produced) land and the (produced) land improvements.[5]

The stock of land improvements can be estimated by the perpetual inventory method (PIM), which accumulates past investment flows and past CFC flows. If an estimate of the value of the combined land asset is available (i.e. the combined non-produced land and produced land improvements), the value of non-produced land could then be determined by subtracting the stock of land improvements from the value of the combined land asset. However, given that the service life of land improvements is often very long, a long time series of investment flows and CFC flows[6] would be necessary to produce a reliable estimate. If land improvements without a sufficiently long time series are excluded from the produced capital stock, then the measured stock of produced capital will be biased downwards, and the residual value of non-produced natural resources will be biased upwards. Fortunately for national accountants, both the United States (US) and the United Kingdom (UK) have long time series for many important types of land improvements. For example, the case study in section 6.1 presents a time series on US land clearing for agriculture back to 1850. Hence, the estimated stock of land improvements could be made quite accurate for the two countries studied, though current measurement practice falls some way short of this.

3.3 What Environmental Assets Can Be Included in Land Improvements?

The definition of land improvements given in SNA 2008 and ESA 2010 is potentially very broad, encompassing any action (and expenditure) that improves land, or prevents its deterioration. SNA 2008 and ESA 2010 provide a small number of examples as detailed in section 3.1. This paper posits many more activities than just these examples, and some of those activities could be very large in value. The remainder of this section gives a few examples.

First, the clearing of rocks, tree stumps, and other natural objects. This can improve the productivity of the land by allowing a structure to be built upon it, allowing a farmer to plough the land without making stops, allowing a hiker to walk on a trail without tripping over rocks, and so on. This activity is often done own account by self-employed small businesses rather than by hired specialists. For example, a farmer might spend some time

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[5] By convention, the land improvements asset class includes the costs of ownership transfer for land. An example of costs of land ownership transfer is the fees paid when buying a house, known as Stamp Duty Land Tax in the UK. This paper's discussion of land improvements excludes costs of land ownership transfer.

[6] National accountants frequently impute CFC from past investment rather than measuring it directly.

each year clearing new land on the borders of his existing fields. Land clearing could have positive externalities like destroying the habitat of crop-damaging locust (Lockwood 2001) or negative externalities like increasing dangerous dust storms (Elliot 2023). What matters for national accountants is not the global impact of land clearing on environmental quality – but rather the local impact on the landowner. This local impact can be measured indirectly by comparing prices for cleared land without otherwise similar uncleared land.

Second, activities that reduce the risk of flooding of adjacent land. One type of flood prevention activity is the clearing of silt and waste from the river, streams, lakes, and ponds. This can improve the productivity of adjacent land by improving water flow and reducing the likelihood of flooding (preventing deterioration of land). Conversely, "leaky dams" consisting of felled trees and other plant material, are installed in streams to slow the flow of water, aiding natural water management and preventing flooding. Both these activities are often carried out by conservation groups or land management businesses. What matters for national accountants is not whether the body of water becomes deeper or shallower – but whether the land is improved through reduced flooding risk.

Relatedly, the category land improvements could also include improvements to bodies of water and other non-produced natural resources. Indeed, surface water including reservoirs, lakes and rivers are included in the definition of land in SNA 2008 (10.175, p.214) and ESA 2010 (3.187, p.85). Improvements to bodies or water are not explicitly included or excluded from definitions of land improvements in national accounting guidelines, but to the extent that the land asset includes such bodies of water, improvements to water should be in scope of land improvements. For example, a natural harbour might be improved by deepening it artificially (Towey 2022). The examples above motivate the inclusion of investment activities that protect adjacent land through investment in bodies of water, rather than improvement in the bodies of water themselves. But investments to improve bodies of water could also be included on their own.

Third, the prevention of soil erosion. Soil erosion has significant costs on the productivity of land for agriculture (Sartori et al., 2019). Soil is treated as a component of land in SNA 2008 (10.175, p.214) and ESA 2010 (3.187, p.85). While national accounting guidelines do not explicitly include soil improvements in the definition of land improvements, since soil is a component of the non-produced land asset, it should be in scope of land improvements. Thus, preventing soil erosion is consistent with preventing land deterioration and is within scope of land improvements. Soil erosion prevention activities include the growing of cover crops,[7] mulching, adding erosion control materials such as crushed stone, wood chips or geo-textile materials, and controlling stormwater runoff (through e.g., rain gardens). Floods can either erode or deposit soil, and so a flood management program may also prevent soil erosion.

Finally, the removal of soilborne parasites (Bleakley, 2007) or other dangerous species could be seen to improve the productivity of land for agriculture and human habitation. Similarly, the removal of pests (such as rats) can raise the value of business property (Almeida et al. 2013). Clearly, an area of land which is free of dangerous, or pest species will be more valuable for economic activity.

[7] Cover crops might also be tracked as cultivated plants. This type of fuzzy boundary between different asset classes is common and does not impact aggregate GDP if each item is counted once.

3.4 Current Measurement Practice for Land Improvements

The definition in SNA is potentially very broad. The examples given in ESA are more limited, but a few other activities could conceivably be within the scope of the SNA definition. The question is then: are any of these activities measured in practice by national statistical agencies when measuring GFCF in land improvements?

In practice, based on an examination of data collection materials and guidance from the US Bureau of Economic Analysis (BEA) and UK Office for National Statistics (ONS), what is actually captured as land improvement investment is small relative to what might captured. For the UK, the ONS estimates GFCF in land improvements by applying a fixed factor to GFCF in the combined "other buildings and structures" asset, informed by data from the Annual Acquisitions and Disposals of Capital Assets Survey (ONS 2022). The question on land improvements in the survey is in the section called "Major Improvements and Construction Work". The land improvements question gives the following specific guidelines:

Include:

- *Land clearance, levelling, draining of marshes, creation of wells, demolitions and other land preparation that improves the quality, quantity and land productivity.*
- *Costs associated with transfer of ownership of land eg land tax and land registry fees.*

Exclude:

- *Cost of land.*

The survey inclusion guidelines are broadly consistent with the national accounting definition and guidelines. However, there are several limitations to this data. First, the sample of the survey is limited to businesses, though much of the relevant unmeasured activity is likely to be undertaken by government and NPISHs which are not sampled. Second, the guidelines on inclusion items are relatively limited, and seems likely to omit the additional examples identified in section 3.3. Third, even though the survey makes clear that work carried out by own staff should be included, no estimates are made (to our knowledge) of own-account investment by self-employed businesspeople in land improvements.

For the US, practices by BEA are likely to bundle the land improvement investment that is tracked together with other construction investment. This bundling does not impact aggregate nominal investment – but it may impact measured aggregate CFC in selected years, given potential differences in rates of depreciation between land improvements and produced structures (dwellings or buildings) or potential differences in the price series used to deflate land improvements and produced structures. The aggregate impact of bundling on CFC in a particular year depends on the exact years in which investment occurs, the lifespan for land improvement, and the lifespan for other construction investment.

4. Cultivated Biological Resources

4.1 Definition of Cultivated Biological Resources

Cultivated biological resources are defined in SNA 2008 as:

"animal resources yielding repeat products and tree, crop and plant resources yielding repeat products whose natural growth and regeneration are under the direct control, responsibility and management of institutional units" (SNA 2008, 10.88, p.205).

Two sub-types of cultivated biological resources are identified in SNA 2008, of which one is "Tree, crop and plant resources yielding repeat products", which is defined as:

"Tree, crop and plant resources yielding repeat products cover plants whose natural growth and regeneration are under the direct control, responsibility and management of institutional units. They include trees (including vines and shrubs) cultivated for fruits and nuts, for sap and resin and for bark and leaf products." (SNA 2008, 10.95, p.205).

SNA 2008 provides further discussion:

"*Gross fixed capital formation in plantations, orchards, etc., consists of the value of the acquisitions less disposals of mature trees, shrubs, etc., including acquisitions of immature trees, shrubs, etc., produced on own account. As explained above, the value of the latter may be approximated, if necessary, by the value of costs incurred in their production during the period: for example, the costs of preparing the ground, planting, staking, protection from weather or disease, pruning, training, etc., until the tree reaches maturity and starts to yield a product. Disposals consist of trees, shrubs, etc., sold or otherwise transferred to other units plus those cut down before the end of their service lives. All agricultural output is at the mercy of the weather. Expected output must take account of normal variations in climatic conditions and exceptional losses should be confined to those outside recent past experience. Disposals do not include exceptional losses of trees due to drought or other natural disasters such as gales or hurricanes, these being recorded in the other changes in the volume of assets account.*" (SNA 2008, 10.96, p.205).

ESA 2010 does not give a specific definition of cultivated plant resources, but rather has a summary of the asset class:

"Trees (including vines and shrubs) cultivated for products they yield year after year, including those cultivated for fruits and nuts, for sap and resin and for bark and leaf products, whose natural growth and regeneration are under the direct control, responsibility and management of institutional units." (ESA 2010, Annex 7.1, p.183).

Both SNA 2008 and ESA 2010 give farm orchards as an example of cultivated plant resources. But the general guidelines apply to long-lived farm pastures, which yield grass for animal consumption rather than fruits and nuts for human consumption. Those same guidelines also apply to cultivated plant resources which yield repeat products in the form of environmental *services* to their owners, rather than goods to their owners. This paper focuses on those plants which yield environmental services.

4.2 Recommended Accounting Treatment of Cultivated Biological Resources

Cultivated biological resources are a fixed asset class in SNA 2008, and SNA 2008's recommended tables put both cultivated animals and cultivated plants in a table of their own (10.2). However, these two types of biological resources are transacted very differently. Cultivated animals are frequently sold alone – and therefore market prices for both new and used assets are readily observable. Hence, investment and capital stock for cultivated animals can be observed using methodologies similar to the methodologies already used for equipment. In contrast, cultivated plants are almost always sold together with the underlying land. Just like with land improvements, transactions in land and valuations of land will typically be for the combination of the (non-produced) land and the (produced) cultivated plant resources. The stock of cultivated plant resources can be estimated with the perpetual inventory method (PIM) by accumulating past investment flows and adjusting for depreciation. National accountants may choose to recognize these similarities by placing cultivated animals in the equipment table and cultivated plants in the structures and land improvement table.

By convention no CFC is recorded on cultivated animal resources under ESA 2010. This is due to paragraph 3.140: "*Consumption of fixed capital shall be calculated for all fixed assets (except animals)* ..." (ESA 2010, 3.140, p.76). If such a treatment were applied to the positive animal investment numbers for the US that are reported in Soloveichik (2021)[8], then the measured stock of cultivated animal resources in the US would be very large and growing steadily. However, ESA 2010 appears to treat all animal deaths as negative investment (3.129(d), p.75) rather than CFC. Net investment can be negative if deaths exceed replacements, and the measured stock of cultivated animal resources does not necessarily grow over time. In practice, the livestock assets discussed in SNA 2008 and ESA 2010 are not environmental assets – and so their treatment has little impact on this paper. [9]

4.3 What Environmental Assets Can Be Included in Cultivated Biological Resources?

Landscaping plants are a major cultivated biological resource in the US (Soloveichik 2021). These landscaping trees and lawns yield housing services to owners through their beauty and soil protection benefits (Donovan et al. 2013). Both landscaping trees and lawns are clearly in the control of the landowner, who normally plants either young trees or grass, protects landscaping while it matures, and manages landscaping throughout its life. When managed properly, landscaping plants have a useful lifespan of centuries (Soloveichik 2021). Landscaping plants are unambiguously owned by the landowner and cannot be removed without the landowner's permission. Furthermore, houses with trees command higher prices and rents than houses without (Han et al. 2021) and therefore the economic value of trees can be inferred with a residual methodology.[10] Hence, landscaping plants are definitely cultivated biological resources according to the SNA 2008 guidelines given in section 4.1.

Seemingly natural forests can also be cultivated biological resources.[11] It may be true that individual plants grow from seeds that travel naturally rather than being planted by a human. But landowners still spend significant resources managing the growth of forests. Controlled

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[8] Consistent with SNA 2008 (section 10.94), that paper treats the value of meat from a slaughtered cow as negative investment. In the US, the value of meat from slaughtered cows is almost always lower than the purchase price for new heifers and therefore farmers only slaughter cows after an illness or injury has reduced their market value. Due to this value difference, net investment almost always positive.

[9] The UK and most European countries have chosen to extend the convention of no CFC to cultivated farm orchards. It is not clear whether they also treat scrapped orchards as negative investment.

[10] Lawns are sometimes required by zoning rules or home-owners association rules – so it is not easy to observe market values for houses without lawns. This unobservability does not mean lawns do not have value.

[11] Products that are held between periods, but when used are only used once, are inventories. A forest which is used only for timber production may be considered an inventory asset rather than a fixed asset. In practice, most forests provide sufficient useful services throughout their life (wildlife habitat, soil protection, seeds for new trees) so that they are classified as fixed assets. Under that classification, the harvest of trees for timber would be tracked the same way as the slaughter of dairy cows for meat.

burning, also known as prescribed burning or prescribed fire, is preventative burning of trees and plant material. It is used to reduce the risk of largescale damage by wildfires by restricting the fire from spreading. Thus, controlled burning can prevent the forest from deteriorating (as much) from fire. Similarly, coppicing is an ancient technique to manage forests and woodlands, that is still used today. Trees are cut to a stump, from which new shoots grow rapidly. This can ensure a regular supply of timber, which can be used for economic purposes. It can also promote the biodiversity and health of woodlands. Just like landscaping plants, seemingly natural forests are unambiguously owned by the landowner and cannot be removed without the landowner's permission. Hence, they are almost certainly cultivated biological resources according to the SNA 2008 guidelines given earlier.

Like seemingly natural forests, undomesticated animals in captivity can also be cultivated biological resources. Zoos and nature reserves make considerable expenditures to breed and maintain undomesticated animals, be they in zoo buildings or in a seemingly natural constructed habitat. The undomesticated animals then provide services like recreation for visitors who like seeing popular animals, subjects for scientific research, and biodiversity preservation for future wildlife restoration. In practice, zoo animals are rarely sold explicitly (Smith et al. 2023) and zoo accountants rarely report the value of animals (Abbot and Tan-Kantor 2022). Hence, the market value of zoo animals cannot be observed, and their imputed value may be too speculative to include in the national accounts.

Finally, undisturbed ecosystems might possibly be considered cultivated biological resources. Modern governments typically protect rare or sensitive ecosystems from poachers, farmers, and other users who might use the land in a way that harms the ecosystem. In some cases, this protection is economically recognized through government acquisition and management of wildlife sanctuaries, parks, and other environmentally important land. In other cases, this protection is done through laws which regulate how private landowners interact with the ecosystems. One could argue that the cost of protecting ecosystems should be tracked as investment and that even undisturbed ecosystems are cultivated biological resources. However, others would argue that undisturbed ecosystems are too lightly managed to fit under SNA's "*direct control, responsibility, and management*" criteria – and so they are not cultivated biological resources.

4.4 Current Measurement Practice for Cultivated Biological Resources

Information on the treatment of cultivated biological resources for the US is given in Soloveichik (2021), an extract of which is given below[12]:

BEA currently tracks dairy cows, beef cows, bulls, sheep, and goats in livestock inventories. Under that treatment, births of those animals add to GDP by increasing "changes in private inventories" (line 11 of NIPA table 1.1.5). Conversely, deaths of those animals (slaughter and nonslaughter) subtract from GDP by decreasing "changes in private inventories." BEA's inventory statistics also reflect value changes associated with animal age, weight, and dairy status.

Private business expenditures on honeybees, horses, farm plants, and landscaping plants do not impact measured GDP. If those items are purchased, then they are tracked as output of

[12] See Soloveichik (2021) for the references given in this extract.

the producing company and intermediate input for the purchasing company. Those two impacts precisely cancel out so that purchases have no net impact on GDP. Own-account cultivated asset production by businesses is not tracked as either output or intermediate input, but time devoted to cultivated asset production are tracked in the labor force statistics. Finally, own-account landscaping production by unpaid homeowners is not tracked as either output or intermediate input and time devoted to it is considered household production and therefore not tracked in the labor force statistics (Kanal and Kornegay 2019).

Government and nonprofit expenditures on landscaping plants do impact measured GDP. For those sectors, BEA measures output based on costs rather than market revenue. Expenditures on landscaping plants are implicitly included in total costs and therefore implicitly included in measured output. Based on the 2012 Economic Census and two surveys of the lawn industry (Barnes et al. 2006 and Bennet and McCarthy-Kersey 2006), this paper estimates that approximately one-quarter of landscaping is owned by the government and a small additional share by the nonprofit sector. Government and nonprofit ownership of other cultivated assets is very small and is assumed to be zero for simplicity.

Finally, the integrated BEA/BLS industry-level production account track the stock of cultivated plants to a limited degree. Even though land is not considered a produced asset, it is still tracked as a natural resource input for the purpose of calculating total factor productivity (Garner et al. 2020). The currently measured value of farmland includes farm plants that are bundled together with land and the currently measured value of developed land includes landscaping plants that are bundled together with land.

The UK national accounts do track cultivated biological resources, but only include dairy cows, breeding beef cows, breeding sheep, and orchards in their analysis. Hence, investment in this asset could be far larger than currently recorded in the UK.

5. Terminal costs

5.1 Theory and definitions

Unlike the other two environmental assets, terminal costs are not an asset by themselves. Instead, they are a component of structures or equipment. In particular, terminal costs are a subset of "costs of ownership transfer" in SNA 2008, which are "costs associated with acquiring or disposing of assets". SNA 2008 explains terminal costs as:

"Just as there may be costs incurred on the acquisition of an asset, there may also be costs incurred on the disposal of an asset. Some of these may be parallel to those costs incurred on acquisition, for example legal fees and disinstallation costs. However, in the case of some significantly large and important assets, such as oil rigs and nuclear power stations, there may also be major costs associated with the decommissioning of the asset at the end of its productive life. For some land sites, such as those used for landfill, there may be large costs associated with rehabilitation of the site. These are referred to collectively as terminal costs." (SNA 2008, section 10.50)

Terminal costs are defined in ESA 2010 as:

"large costs associated with disposal [of fixed assets], e.g., decommissioning costs of nuclear power stations or clean-up costs of landfill sites" (ESA 2010, 3.129(h), p.75).

Thus, costs incurred to dispose of fixed assets at the end of their useful life are recorded as investment and the accumulation of future costs during an asset's life are recorded as CFC (although SNA 2008 and ESA 2010 differ in the time of recording terminal cost investment and CFC). SNA makes this explicit: *"Any terminal costs incurred at the end of an asset's life such as those required to render the structure safe or to restore the environment in which it is situated"* (SNA 2008, 10.51(f), p.200). This will often be demolition of the existing structure, which is sometimes part of the costs of new investment in buildings and structures.

For some assets, the costs of disposal are smaller than the scrap value – and therefore those costs can be subtracted from the scrap value to get a small positive value at the end of their useful life. However, most structures and many types of equipment have a large disposal cost and a minimal scrap value – and therefore have a negative net value at the end of their useful life. SNA 2008 makes this situation clear:

"Immediately before the disposal, the value of the asset will have a negative value which is reduced to zero when the terminal costs incurred are treated as gross fixed capital formation. The apparent oddity of an asset with negative value reflects the fact that these assets yield negative services to their owners. Consider an unsafe and unusable building resulting from years of decay. Such a building might create fines and other legal problems for its owner as long as it stands. The owner of that building not only could not sell it but would have to pay another unit to take over responsibility for the asset." (SNA 2008, 10.161, p.212).

5.2 Recommended Accounting Treatment of Terminal Costs

Unlike the other two assets, terminal costs do not have their own line in SNA 2008's recommended tables (10.2). Instead, they are supposed to be tracked as a component of the structure or equipment that they are associated with. For example, suppose that an old manufacturing plant has a replacement cost of $50 million but would require $25 million of pollution remediation before it could be sold, for a net value of positive $25 million. Or an old manufacturing plant could have a replacement cost of $25 million but would require $50 million of pollution remediation before it could be sold, for a net value of negative $25 million. This potential flip from a positive capital stock value to a negative capital stock value is explicitly noted by SNA 2008 and does not present any conceptual problems. But it is possible that the flip might confuse users. National accountants may choose to report replacements costs and terminal costs separately so that users can better understand the net capital stock numbers shown in the summary tables.

The GDP revisions associated with tracking terminal costs are conceptually similar to the GDP revisions associated with land improvements and cultivated biological resources. Just like those assets, investment by the market sector raises measured GDP, and CFC in the government or NPISH sector raises measured GDP. But the timing of the GDP revisions is now flipped. With terminal costs, CFC occurs before investment. Therefore, measures of government or NPISH output increase immediately while measures of private output only increase later.[13] This timing flip is particular important for terminal costs with a long lag between CFC and investment.

[13] For some asset types, investment may be either completely impossible or economically inefficient. For example, global species extinction cannot be reversed no matter what. And even local species extinction may be too costly to reverse. In those cases, the national accounts would show CFC without associated investment.

Similarly, the capital stock of terminal costs can be estimated with the same perpetual inventory method used to estimate the stock of land improvements and cultivated biological resources. However, there is one important difference. Unlike land improvements and cultivated biological resources, terminal costs have a negative market value. As a result, excluding them from the produced capital stock biases the measured stock of produced capital upwards and biases the residual value of non-produced natural resources downwards. It is theoretically ambiguous whether the net bias from excluding all three produced capital classes is positive or negative on average.

In practice, reliable measurement of terminal costs is difficult. Neither the US nor the UK publish much historical data on industrial contamination, waste treatment, or pre-emptive demolition. Furthermore, the historical data that are published tend to be measured through the lens of concepts that are not consistent with national accounting concepts. As a result, much more research would be needed before a comprehensive time series of terminal costs could be included in the national accounts. The case study shown in section 6.3 of this paper focuses on one terminal cost example where reliable data already exist.

5.3 What Environmental Assets Can Be Included in Terminal Costs?

The definition of terminal costs given in SNA 2008 is potentially very broad, encompassing any costs associated with disposing of an asset at the end of its useful life, and particularly assets that have negative effects on their local environment (such as the land on which it is situated). SNA's discussion focuses on costs which are directly associated with a physical structure (e.g. oil rigs, nuclear power stations). But costs that are indirectly associated with a physical structure could be very large in value. In addition, some costs may be associated with assets other than structures.

First, the local pollution associated with a structure or immobile equipment. For example, if a mine shaft can be considered an asset (providing metal, coal, oil, or other valuable materials), the cost of disposing or remediating toxic waste surrounding a mine shaft can be considered terminal costs. Manufacturing plants, utilities, and even residential housing can also generate toxic waste that can be considered a terminal cost. In many cases, the cost of disposing or remediating toxic waste is so large that property owners choose instead to store the toxic waste indefinitely. This absence of restorative investment does not negate the CFC which occurred when the toxic waste was originally created. Hence, local pollution is almost certainly a terminal cost according to the SNA 2008 guidelines given earlier.

Second, the local ecosystem damage associated with cultivated biological resources or a structure. For example, a cultivated landscaping tree might start growing into the basement and damage the house's foundation. Or a vacant building may become a breeding ground for rats. In some cases, local ecosystem damage is even done intentionally by entities that do not consider the long-term downside. For example, a government might try to 'improve' the land by wiping out wolves (Coleman 2008) and then later discover that wolves are necessary to prevent deer overpopulation. Just like with toxic waste, the cost of restoring an ecosystem may be so large that property owners choose instead to live with a damaged ecosystem indefinitely. Once again, the absence of restorative investment does not negate the CFC which occurred when the ecosystem was damaged. These local ecosystem damages are almost certainly a terminal cost according to the SNA 2008 guidelines.

Third, the soil erosion associated with land improvement or structures. For example, a farmer who clears a prairie might enjoy bountiful crops during wet years – but see their topsoil blow away in dry years. Or a river dam might could allow for easy irrigation in dry years – but cause floods which wash away topsoil in wet years. If the soil erosion is steady and predictable, then it is almost certainly CFC and a terminal cost according to SNA 2008 guidelines. But an unexpected disaster like the Dust Bowl in the US may be tracked as 'other change in volume of assets' and therefore would not be either CFC or a terminal cost.

5.4 Current Measurement Practice for Terminal Costs

We judge that only nuclear decommissioning costs and demolition that is carried out as part of a construction project are recorded as investment in terminal costs in the US and UK national accounts. Many other expenditures should also be included, such as the decontamination of industrial plants or sites (other than nuclear sites); the clean-up of non-nuclear hazardous waste (such as landfill sites and factories); treatment of products that have the potential to cause long-term negative effects on human health or the environment; and pre-emptive demolition (i.e., demolition not for immediate construction). Unfortunately, neither the US nor the UK publish details on their specific treatment of terminal costs. As a result, it is difficult to determine exactly which expenditures are currently recorded as investment or whether pollution and other terminal costs are currently included in CFC.

6. Case studies

This section will present three separate case studies on the US: one for land improvements, one for cultivated biological resources, and one for terminal costs. These three case studies were all selected because relevant data had already been collected by the US Department of Agriculture, the US Department of Energy, and other official sources. The case studies reported may not be representative of environmental assets in general. As a result, extrapolation from those case studies does not necessarily yield a reliable estimate of the total GDP revision associated with tracking all environmental assets that are in scope for the national accounts. Much more research would be needed before the national accounts could be revised to include all produced environmental assets.

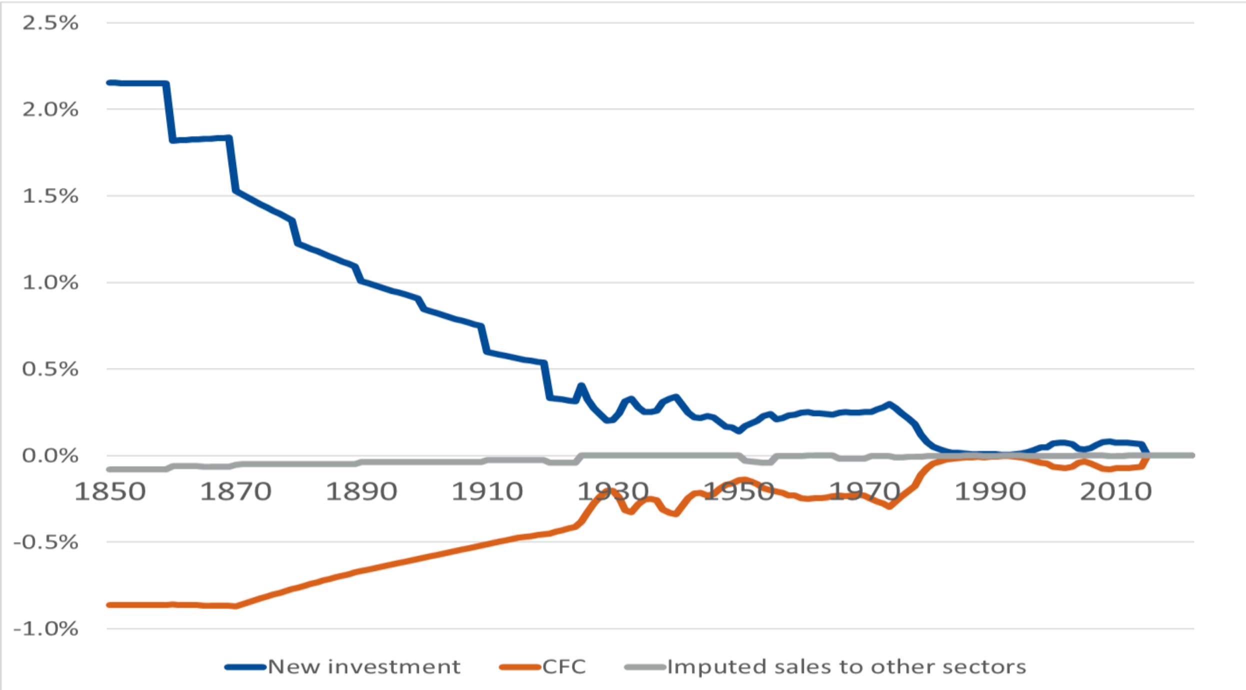
6.1 Land Improvements: Land Clearing for Agriculture

The first case study focuses on land clearing for agriculture. In the 1800s, pioneers in the US felled trees, pulled stumps, broke prairie sod, and moved rocks on their new homesteads. Land clearance is explicitly recognized as investment in SNA 2008 (see section 3.1 for discussion). But, to our knowledge, none of this historical investment is tracked as GFCF in the current US national accounts. Clearing forest land is very labor intensive and it raises the market value of farm acreage enormously while clearing prairie land is less labor intensive and has a smaller impact on market values (Primack 1962). Hence, investment per acre was highest during the mid-1800s when pioneers were moving into forested areas in the eastern and mid US – but lower per acre during the late 1800s when pioneers were moving into the prairie areas in the western US.

The Census of Agriculture provides data on improved farmland acreage and therefore implicit data on land improvement. This paper assumes that all increases in improved farmland between Censuses in a particular region are due to new land clearance.[14] This paper then uses historical information on each region's native vegetation to split land clearance between forest land clearance, which raises market value enormously, and prairie land clearance, which has a much smaller impact on market value. From 1925 onwards, land clearance quantities and prices are calculated using county-level data on cropland quantities and land prices. Before 1925, land clearance quantities and prices are extrapolated using state-level data on improved farmland quantities, estimates of nominal GDP per capita, and estimates of the quantity of labor required to clear forests (Primack 1962). Historical data are only available in Census years, so the time series is smooth between Censuses in early years but more volatile later.

Figure 1 shows that land clearing for agriculture was an important investment category in the 1800s, but much less so over the past century. Land clearing was worth about 1.5-2% of GDP in the late 1800s, falling steadily to around 0.3% of GDP from the early 1900s to the 1970s, and falling to near zero since then. Therefore, tracking land clearing has only a small impact on either measured investment or measured CFC after the US national accounts started in 1929, and little impact over recent decades.

Figure 1: Changes to the Cleared Land Stock in Agriculture as a Share of US GDP



National accountants who are only interested in measuring the current economy of developed countries might conclude that land clearing is a minor category that can be ignored. But many developing countries are at a similar economic stage as the US in the 1800s (Ravallion 2014), and some of them are currently clearing large quantities of natural environments for farming (Pendrill et al. 2019). Accordingly, national accounting guidelines which are written for a

[14] Non-response, misreported, and boundary changes can create spurious changes in reported cropland. This paper adjusts for West Virginia splitting from Virginia and a spike in non-response after the Civil War in the defeated Confederacy (Steckel 1991) but does not adjust otherwise.

broad range of countries may want to emphasize the importance of including land clearing investment.

Figure 1 also shows that small but non-zero quantities of land cleared for agriculture have been sold to other sectors. For example, a developer might buy farmland to build a new housing complex. Like all asset sales, these sales are treated as negative investment by one sector and positive investment by another with no net impact on aggregate investment (SNA 2008, section 10.40). Accordingly, the negative change in capital for the agricultural sector shown in Figure 1 are precisely cancelled by a small positive change in another sector. National accountants who are solely interested in aggregate GDP can disregard them. But national accountants who are interested in measuring savings by industry, productivity by industry, or other industry statistics may still want to track them to get accurate measures of the stock of produced capital and the stock of non-produced natural resources by industry.

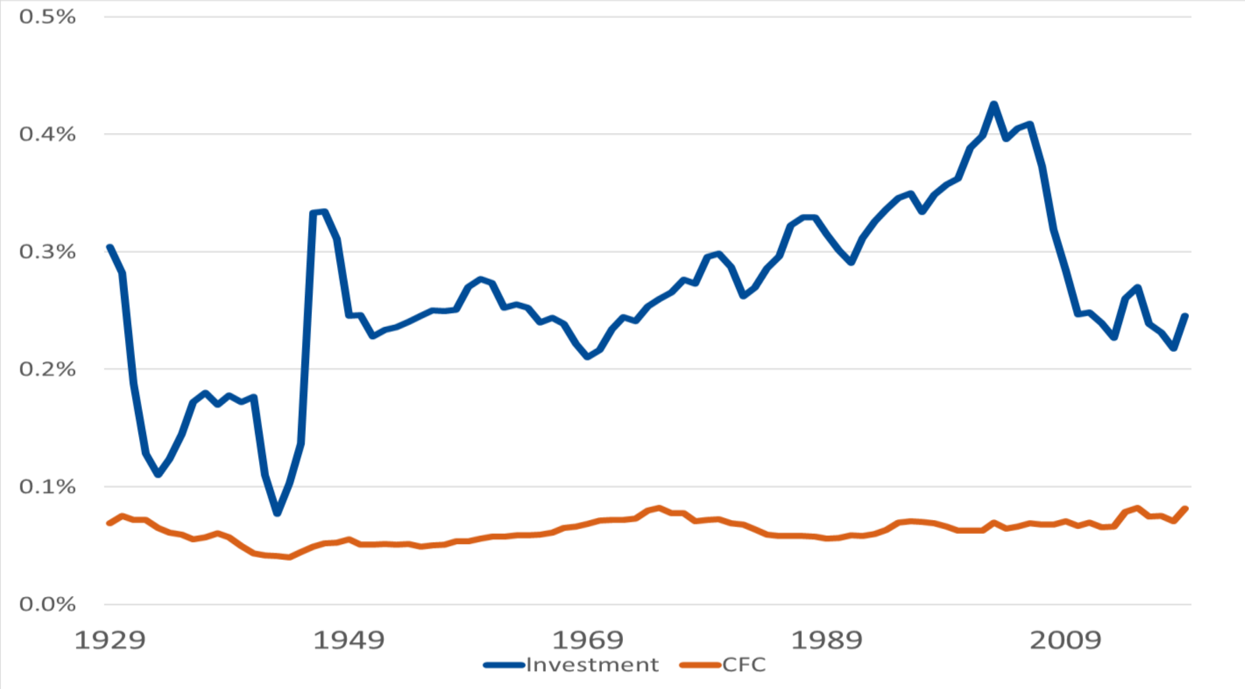
6.2 Cultivated Plant Resources: Landscaping Plants

The second case study focuses on landscaping plants. Even though people enjoy trees and grass, very few structures are built in the middle of natural environments. Instead, construction companies typically start out with cleared land (whether they cleared it themselves or bought it pre-cleared from a farmer), build a structure in the middle, and then plant young trees and grass around the structure. Furthermore, property owners often plant additional young trees if they want to enhance their existing landscaping or if they need to replace depreciated trees.

The Census of Agriculture provides indirect information on landscaping investment. It may be true that almost all landscaping spending is associated with construction companies, homeowners, and other entities outside the agricultural sector. But the agricultural sector provides crucial inputs like young trees and lawn sod to landscapers. Both the nominal revenue earned from those crucial inputs and a measure of price per unit are available in the Census of Agriculture back to the early 1900s. A previously published paper (Soloveichik 2021) calculated annual landscaping investment by multiplying historical information on agricultural revenue from crucial landscaping inputs with expert estimates of the ratio of total landscaping investment to spending on the crucial inputs tracked in the Census of Agriculture. More details on the methodologies used to calculate investment, capital stock, and CFC are available in that paper. Figure 2 uses data that was presented in that paper and posted for public use.

Figure 2 shows investment and CFC associated with landscaping plants. Investment in landscaping plants has varied around 0.1-0.4% of GDP between 1929 and 2019, while CFC has been just under 0.1% of GDP. Thus, effects of tracking this asset would be non-trivial. By these estimates, investment in landscaping plants has exceeded CFC for every year since the national accounts started in 1929. As a result, the stock of landscaping plants has grown steadily over time. Even if the global environment is suffering from species extinction and pollution, the local environment that people in the US see every day has improved thanks to more mature trees and larger lawns. Accordingly, tracking environmental assets in the national accounts can sometimes reveal good news for people.

Figure 2: Nominal Landscaping Plants as a Share of GDP, US



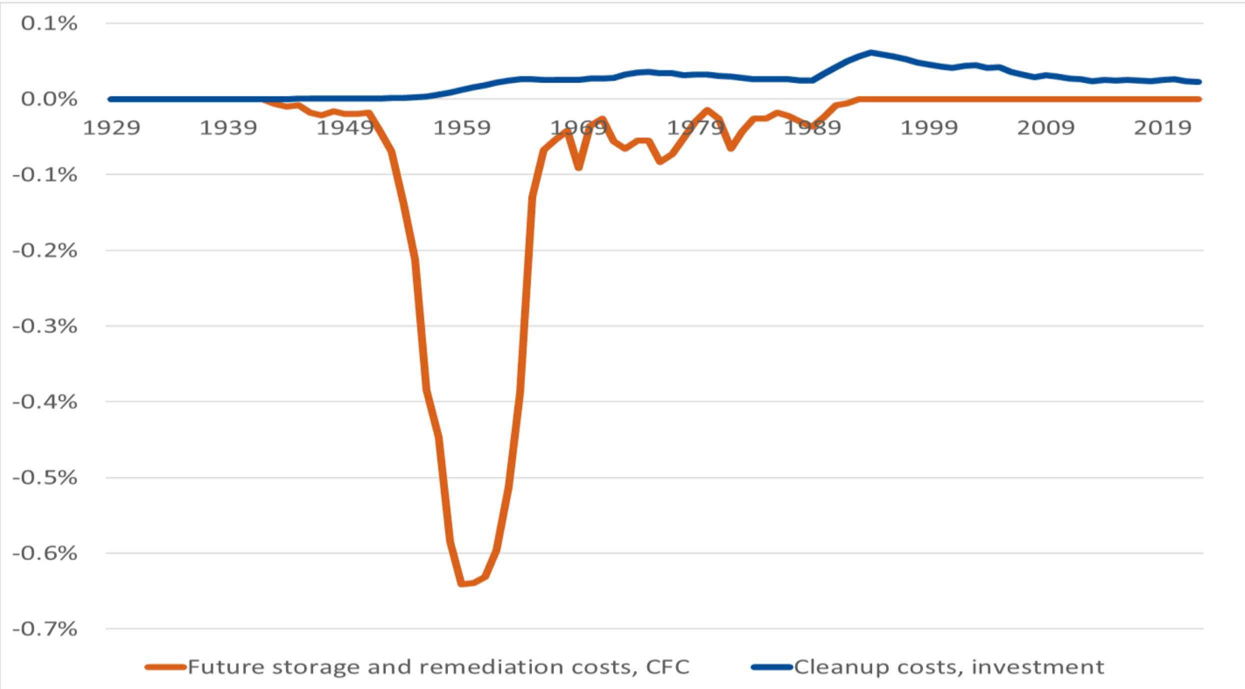
6.3 Terminal Costs: Nuclear Bomb Manufacturing Plants

The third case study focuses on the dangerous radioactive waste associated with nuclear bomb manufacturing plants (Schwartz 1998). It may be true that both the fallout associated with nuclear bomb detonation (in war or in testing) and the military services provided by nuclear bombs are global and therefore provide externalities which are out of scope for GDP. But the radioactive waste associated with nuclear bomb manufacturing is local and therefore in scope for GDP. BEA's published statistics already track the construction of those plants in measured structures investment, and the physical deterioration of the manufacturing plants in measured structures CFC. This case study broadens both measures to include the creation of radioactive waste as a component of the CFC of those structures, and the remediation of radioactive waste (through intentional cleaning or natural decay) as investment in terminal costs associated with those structures. Storage of long-lived radioactive waste is neither treated as CFC nor investment. Rather, storage costs are considered a negative capital service that is subtracted from the positive capital service associated with the physical structure.

The Department of Energy provides information on nuclear bomb manufacturing plant terminal costs. Since the 1980s, they have been responsible for the management of radioactive waste and they have published regular data on expenditures for remediation, expenditures for storage, and expected future costs (Schwartz 1998) (Anderson 2021) (Vartabedian 2023). This paper uses expert judgment to extrapolate those expenditures back to the nuclear bomb program's start in the 1940s. If historical discount rates and historical prices were known with certainty, it would be straightforward to calculate the net present value of future remediation costs and future storage costs. For now, this case study assumes a real discount rate of 4 percent per year for government costs,[15] a price index for remediation which tracks hourly costs for tax preparation (Soloveichik 2023), and a price index for storage which tracks BEA's published price index for military buildings. This case study also assumes that the quantity of radioactive waste created in each year tracks the annual output of purified uranium 235.[16] Based on those assumptions, this case study uses a spreadsheet to calculate CFC, which is defined as the net present value of costs associated with new nuclear bomb manufacturing, for every year from the early 1940s, when nuclear bomb manufacturing started, until the present.

Figure 3 shows that most radioactive waste was created during the early Cold War era.[17] Because that CFC occurred so far in the past, one might think that it has little impact on the measured capital stock now. In fact, many types of radioactive waste have such a long lifespan that they are almost as dangerous in 2024 as they were in 1954. Furthermore, prices for the structures used to store radioactive waste have risen faster than overall GDP prices. Due to these two factors, the net present value of future storage and remediation costs was nearly half a trillion dollars in 2022.

Figure 3: Nuclear Bomb Manufacturing CFC and Investment as a share of GDP



[15] That discount rate is higher than the rate implied by government bonds (Jorda et al. 2019). However, using the government bond rate is problematic because it can yield an infinite net present value when future costs rise faster than the government bond rate.

[16] Both secrecy and speed may increase the quantity of radioactive waste created per unit. In addition, learning-by-doing may have made production more efficient over time. This paper recognizes all those factors by assuming that uranium 235 purification during World War 2, when the nuclear bomb program was both new and secret, was twice as dirty as uranium 235 purification afterwards.

[17] It may be true that the only two nuclear bombs used during war were detonated in 1945 as part of World War II. But those nuclear bombs were followed by many others that were either detonated during testing or stockpiled for a potential nuclear war with the Soviet Union. Accordingly, nuclear bomb *creation* peaked long after nuclear bomb *usage*.

Measured GDP increases when radioactive waste creation is treated as a type of CFC.[18] As described in section 2.3, measured GDP increases by the value of additional investment in the private for-profit sector, and by the value of additional CFC in the government and non-profit sectors. In this case study, we measure additional investment in terminal costs in the government sector, which does not add to GDP since that investment is already included in GDP as government final consumption expenditure – tracking it as GFCF would, however, entail a reclassification. This case study also measures additional CFC in the government sector, which raises GDP, since non-market output by government units is valued by costs, and CFC is one of those costs. This additional cost is additional CFC associated with the nuclear bomb manufacturing structures, and reflects that these structures create major costs for which restorative investment would be needed at the end of the assets' useful life to return the site to its original condition.

Some of the radioactive waste was created by private for-profit businesses that the government contracted with, and some was created by the government directly. Accordingly, one might argue that only radioactive wastes which were created by the government directly added to GDP. However, the contracts which governed nuclear bomb manufacturing during the Cold War explicitly stated that the government was liable for environmental damage and cleanup costs (Schwartz 1998). Hence, this paper treats all radioactive waste as government CFC, and therefore the entire CFC shown in Figure 3 would be added to measured government output. As a result of this treatment, measured GDP during the early Cold War era would increase noticeably, with a peak increase of 0.64 percent in 1960.

The 0.64 percent GDP increase calculated in the previous paragraph is likely a lower bound. First, the Department of Energy uses a conservative methodology for estimating future costs – and therefore the official cost projections are likely an underestimate of expected costs. Second, if one were interested in including externalities, the costs of nuclear bomb fallout and other dispersed radioactive waste (Black et al. 2019) might also be included, but only the cost of local radioactive waste are included in these data. Finally, this GDP revision only counts the CFC associated with radioactive waste once in current government output. If some of the radioactive waste was generated during military research, then it should be counted twice: once in government research investment and once in imputed capital services from government research stock. If all the treatments listed above were adopted, then measured GDP during the early Cold War era might increase by 1 percent or more.

7. Conclusion

This paper considered a particular type of environmental issue in the national accounts: produced assets that either improve or damage the environment. This paper focused on three produced fixed asset classes: land improvements, cultivated biological resources, and terminal costs. SNA 2008 and ESA 2010 both include those all three of those asset classes in their official guidelines – but neither the US nor the UK record many produced environmental assets in their published national accounts. The paper then presented three preliminary case studies to illustrate the potential importance of each asset class.

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[18] This seemingly perverse results highlight the fact that GDP is a measure of output rather than welfare. A sophisticated measure of social welfare might replace the assumed value of nuclear bombs with an estimate of their actual value to society.

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