A Capital-based Sustainability Accounting Framework for Canada

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Introduction

This paper presents a proposed approach to the creation of a measurement system for sustainable development.[1] The system uses an expanded notion of capital as its conceptual framework. Its analytical framework is that of the System of National Accounts (SNA).

The paper is divided into four sections. The first discusses an interpretation of sustainable development based on welfare and how capital can be used to frame this interpretation. Next, the concept of capital is explored in more detail as it applies to the environment. This is followed by a description of a system of environment accounts based on capital proposed recently by Statistics Canada. A brief discussion of issues for further exploration concludes the paper.

A welfare interpretation of sustainable development

The term sustainable development has been the subject of much discussion since its popularisation in the Brundtland Commission's famous 1987 report *Our Common Future*.[2] Regrettably, for all this discussion the world has yet to reach a consensus on its meaning. A necessary first task in any work on sustainable development is, then, to state clearly how the concept is interpreted for the purposes at hand. The interpretation here is as follows.

First, **development** is assumed to be the on-going increase in human welfare. Welfare, in turn, is assumed to be a function of consumption of goods and services (products) that generate utility for the consumer. Both marketed and non-marketed products are assumed to generate utility for consumers. Thus the terms "consumption" and "consumer" are used more broadly here than is typically the case. Consumption takes place whenever an individual (a consumer) benefits from the enjoyment or use of *any* good or service, regardless of the price paid for it.

Human welfare is assumed to have no upper limit; that is, it is always possible to find a new pattern of consumption that will generate a higher level of welfare than that which exists at the moment. It is assumed, however, that consumption of some products results in external effects that, beyond certain levels, will lead to utility-decreasing reductions in

1. The opinions expressed here are those of the author and should not be taken to represent the official position of Statistics Canada. The author wishes to thank Karen Wilson and Martin Lemire of Statistics Canada for providing helpful comments.

2. World Commission on Environment and Development, 1987, *Our Common Future*, Oxford: Oxford University Press.

the availability of other products. For example, the consumption of manufactured goods may result in the release of pollutants that reduce the capacity of the environment to provide key ecosystem services. Therefore, it is only exceptionally true that development can occur in the long run simply by increasing overall consumption levels following their current pattern. It is almost inevitable that this will result in excess consumption of some products and reductions in the availability of others. Rather, for development to occur **sustainably**, it is necessary to recognize situations in which the increased utility derived from the consumption a particular product is not outweighed by the loss in utility from an associated decrease in the availability of another product.

Put another way, development can only be sustainable when human activities do not broadly and persistently undermine the capacity of certain essential systems to provide welfare-increasing consumption opportunities. Three such systems can be identified: the environment, the economy and society. Each one provides products that are fundamental to human development. Each is fragile and subject to perturbation from human activities and each is inter-related with the others. If welfare is to continually increase, each of these systems must be maintained in and of itself. It is not conducive to sustainability that consumption of the products from one system diminishes the capacity of the other systems.

Yet it is not assumed here that each of these systems must be maintained unchanged. Rather, substitution possibilities are assumed between the systems. That is, consumers can choose to consume more of the products offered by one system (say, the economy) and fewer of those offered by another system (say, society) while maintaining or enhancing their overall welfare. Such substitutions have taken place throughout history and will no doubt continue in the future. The extent to which they will take place is a function of human values, information with which to assess tradeoffs, political factors and many other variables that are beyond discussion here. While it is taken for granted that such substitutions will occur, the possibilities for welfare-increasing substitutions are not assumed to be without limit (this point is taken up again later in the paper).

Capital as a conceptual framework

When economists speak of the capacity of the economic system to generate products on an on-going basis, they refer to its *capital stock*. This stock comprises tangible goods such as machinery, equipment, buildings and infrastructure and intangible items such as computer software and specialized knowledge. Capital goods (or assets) such as these are required today in order that production take place tomorrow. Economists have identified several general characteristics of such goods. First, it is not the goods themselves that are of value, but the services they offer. Second, they tend to depreciate over time; that is, the quality of the services they produce generally declines as the goods age. For this reason, economic production is not sustainable in the long-term unless there is continual investment to replace capital goods as they wear out.

Many researchers have noted that it is not just machinery, equipment and the like that share the characteristics of capital goods. They note that elements of all three essential systems mentioned above (the economy, the environment and society) have value for the services they render to humans and are subject to deterioration unless maintained. These elements, it is argued, qualify for treatment as capital just as much as more traditional goods.

The most widely studied of these relatively newly recognized forms of capital is the labour force, which is now commonly accepted in the academic literature to comprise a stock of *human capital*. Human capital has been defined as “the knowledge, skills, competences and other attributes embodied in individuals that are relevant to economic activity”.[3] Its flow corollary is the labour services that are used in the economy. The investments needed to maintain it are education and, somewhat more controversially, healthcare and on-the-job training.

More recent and less well-studied from a capital perspective are **natural capital** and **social capital**. Natural capital is the term used increasingly to describe those elements of the environment that yield resource materials and ecosystem services. Unlike other forms of capital, no explicit human investment is required to maintain natural capital. Rather, what is needed is that human impacts on the environment are limited so that they do not represent a *disinvestment* in natural capital.[4]

Social capital is a more recent term that describes the capacity of societies to generate trust, faith, tolerance, ingenuity and other human qualities that are essential for development. The investments needed for its maintenance are the creation and maintenance of effective public institutions and processes.

It is argued here that this emerging, broadened concept of capital represents the most suitable conceptual framework for the development of a sustainable development information system. To begin with, there exists a well-developed body of thought around the concept of capital that provides clear guidance on *what* such a system should measure. Of paramount importance is identification and measurement of the capital goods (or assets) that provide the service flows necessary for development. Along with measurement of these assets, measurement of the factors that lead to their increase (investment) and decrease (depreciation) is essential to the capital approach.

As much as the approach provides guidance on what should be measured, it also dictates what *not* to measure. For one, measurement of current consumption is not required. While consumption is an important indicator of current welfare, it says nothing about the possibilities for sustaining welfare in the future.

Also excluded is measurement of the individual elements that comprise assets (for example, the individual pulleys, bolts and gears that make up a machine or the individual species that make up an ecosystem). These elements do not, in and of themselves, generate service flows. Only when combined in the form of a functioning asset do they do so. Measurement of the complete asset itself is, therefore, all that is required from the capital perspective.

It is important to underline the extent to which this guidance on what and what not to measure simplifies building a sustainable development information system. Each of the three systems essential to development is extraordinarily complex and the number of variables that could possibly be measured for any of them is enormous. Measurement of them all is, obviously, out of the question. Some means is required of identifying a manageable set. In the absence of a theoretical framework as a guide, the selection of variables would be subjective and may tend toward a large set since nothing would

3. Organisation for Economic Co-operation and Development, 1998, *Human Capital Investment – An International Comparison*, OECD: Paris, p. 9.

4. It must be noted that the 1993 SNA includes several categories of tangible non-produced assets that would fall under the heading of natural capital, although that term is not used in the SNA. These include certain land areas, proven sub-soil mineral and fossil fuel reserves, certain non-cultivated biological assets and certain water resources. In general, these are recognized as assets in the SNA only insofar as they are privately held and profitable under current price and technology conditions.

constrain the number chosen. With the notion of capital as a guide however, it is relatively straightforward to determine the variables that must be measured; that is, those related to the extent of assets and their increase and decrease. Moreover, the number of variables (assets) that requires measurement is sufficiently constrained that the practical problem of building the information system is manageable.

A second strength of the capital approach is its close alignment with the notion of inter-temporal justice inherent in sustainable development. The Brundtland Commission emphasized the importance of meeting the needs of present generations while protecting the right of future generations to meet their own needs. Similarly, economists and accountants have always argued that a portion of current income must be set aside for investment in new capital goods to replace those that wear out. It is, they note, the responsibility of current consumers to forego some consumption so that future consumers will inherit at least the same possibilities for economic production as are enjoyed today.

As noted earlier, sustainable development requires maintenance of the welfare-generating capacity of not just the economic system but of the environmental and social systems too. From a capital perspective, this simply means extending the economic concept of investment from the economic domain to the environmental and social domains. While the nature of what can be considered investment in the environmental and social domains is quite different from that in the economic domain, the notion is nonetheless useful in guiding the creation of a sustainable development information system.

A final strength of the capital approach is the familiarity to the average citizen of its practical implications, if not its theoretical underpinnings. Nearly all people understand that they must maintain their homes, their belongings, their finances and, indeed, their bodies if these things are to continue to provide them with the security, income and health that are essential to a good life. If presented with the notion that nations must similarly maintain their economies, their natural environments and their social structures to ensure long-term development, most people would intuitively grasp the importance of doing so. For this reason, it seems reasonable to contend that they would comprehend without difficulty a system for measuring sustainability based on capital.

To summarise, development is assumed here to be a function of the consumption of goods and services provided by three essential systems, the economy, the environment and society. It is sustainable when the ability of these systems to provide products over the long term is not widely and persistently compromised by human activities. The elements of the systems that ensure their long-term ability to provide products are labelled assets, a term borrowed from the economic literature. The concept of an asset is considerably broadened here to include not just the produced assets of the economy (machinery, equipment, buildings, etc.), but elements of all three systems that are of value for the services they offer and are subject to deterioration. This expanded notion of capital is useful as a basis for a sustainable development information system because it offers explicit guidance on what (and what not) to measure, it aligns well with the inter-temporal aspect of sustainable development and it is intuitively understandable for average citizens.

The next section expands on one of the three categories of capital, natural capital, to demonstrate how the theoretical framework can be operationalised in terms of measurable variables.

The environment from a capital perspective

The environment contributes to human welfare through the provision of both material and service flows. The materials it provides include metals and minerals, biological products (*e.g.,* timber), water and fossil fuels. The service flows range from the assimilation of waste materials to the regulation of the global climate. They are defined broadly here to include pure utility flows; for example, the psychic enjoyment of wilderness.

According to the capital approach, the great complexity of the environment and humankind's relationship to it can be simplified by focussing on the distinct stocks of natural resources and individual ecosystems that are the source of these material and service flows. These stocks and ecosystems are the environmental assets that contribute to welfare and must be included in the measurement of sustainability. Collectively, they are labelled *natural capital*.

It is important to note that the adoption of the economic term capital by no means limits the consideration of the welfare benefits of the environment to economic benefits alone. On the contrary, although economic benefits are part of what natural capital offers, they are just a subset of the complete range. The complete range can be grouped into two broad categories: use benefits and non-use benefits.

Use benefits are, as the name implies, associated with the active human use of an environmental asset. For a use benefit to be realised, people must be engaged in activities that depend upon a current-period flow of either a material or a service from the environment. Use benefits can be further divided into two sub-categories: direct-use benefits and indirect-use benefits.

- **Direct-use benefits** include those derived from the use of the environment as a source of materials, energy or space for human activities. Also included are the benefits associated with non-consumptive uses of the environment, such as recreation. Some direct-use benefits are clearly economic in nature since they manifest themselves in the context of economic activity (the value of resource extraction for example). Others are non-economic; that is, they provide benefits for which there is no associated transaction in the marketplace. The benefits derived by humans from the aesthetic appreciation of the environment are an example of non-economic direct-use benefits.

- **Indirect-use benefits** are those associated with human use of the services provided by ecosystems. They do not derive from the active use of ecosystems themselves, but rather from the passive use of services that ecosystems render free of charge. They include the benefits humans derive indirectly when they enjoy the clean air and water, stable climate and protection from the sun's damaging ultra-violet radiation afforded by ecosystems. By their nature, indirect-use benefits are always non-economic, as there is never any market transaction associated with the indirect use of the environment.

The second broad category of environmental benefits is that of **non-use benefit**s. These are derived from the continued existence of elements of the environment that may one day provide *use* benefits for those currently living or for generations to come. An example is the benefit derived from maintaining a rain forest to protect sources of genetic material for development of drugs or hybrid agricultural crops in the future. As with indirect-use benefits, non-use benefits are purely non-economic.

The categories of natural capital

Three main categories of assets provide the environmental benefits listed above: **renewable and non-renewable resource stocks** (*i.e.*, sub-soil resources, timber, fish, wildlife and water), **land** and **ecosystems**. Each of these plays a different role in terms of its contribution to environmental welfare and each is subject to differing impacts from human activity.

Non-renewable resources: Non-renewable resources represent stocks from which materials can be withdrawn for use in human activity. These materials provide direct-use benefits as inputs into industrial processes and in private activities. Because sub-soil resources do not have the capacity to renew themselves, except in geologic time, these resources are subject to permanent depletion as the result of use. They do not play an important role in ecosystems, so their use does not inherently lead to a qualitative degradation of the functioning of the environment. In practice however, the exploration and development activity required to make these resources available can cause significant degradation of the environment, not to mention the degradation of the environment at the local, regional and even global scale that can result from the *use* of resources once extracted.

Renewable resources: Renewable resources (trees and other plants, fish and wildlife and water) also represent stocks from which materials can be withdrawn for use in the economy. Unlike sub-soil resources, these resources can renew themselves under appropriate conditions. If withdrawals within a given period are less than or equal to natural renewal, there need be no depletion as a result of human use. Of course, withdrawals are not always less than renewal, so depletion can and does occur. Fish resources are an obvious example. Aside from the possibility of depletion, renewable resources are also subject to qualitative degradation as a result of human use. Qualitative degradation does not necessarily reduce the absolute size of renewable resource stocks, but makes them less productive or less valuable. This degradation can be the result of harvesting activities (*e.g.*, changes to the natural age- and species-distribution of forests, unintended mortality of non-target fish species); of pollution impacts (*e.g.*, acid rain); and of disturbance from urbanisation, agriculture, recreation and other land use changes. This degradation can negatively affect welfare because of reductions in use benefits (*e.g.*, lower quality material supplies, reduced aesthetic value) or non-use benefits (reduced options for the future).

Land: When land is considered as natural capital, it is with reference to its role in the provision of space.[5] Land benefits humans in two ways from a spatial perspective. First, there are the direct-use benefits associated with the occupation of land for human purposes (dwellings, transportation infrastructure, agriculture, recreation). Second, there are the indirect-use benefits associated with the services of the ecosystems that occupy land areas.

Land area is, of course, not subject to quantitative depletion (at least not yet – climate change may change this if sea levels rise sufficiently). Nor is it subject to qualitative degradation in the same way as renewable resources. However, land areas of specific types can be augmented or diminished as a result of changes in the way in which land is used. For example, increasing use of land for urban purposes necessarily means reduced

5. Soil is not a part of land in this respect, although it clearly does fit within the framework of natural capital. It could be treated either as a natural resource stock or, more reasonably, as a component of terrestrial ecosystems.

use of land for other purposes (agriculture, recreation, wildlife habitat, etc.) in areas around growing cities.

It is not clear *a priori* whether a given change in land use represents a net benefit or loss for human welfare. Clearly, at the margin it is generally assumed that decisions regarding land use are made such that the more highly valued use wins out over the less highly valued. There are two reasons to suspect that this assumption might not always be true in the long run. First, it may be that decisions that are sensible at the margin from a private perspective do not make sense in aggregate from a societal perspective. Clearly, a farmer with 100 hectares of land on the edge of a major city may see very clearly that his land is valued much more highly for housing than it is for crop production. However, when one recognizes that most good farmland is found near settled areas, one sees that the private decision to convert farmland to subdivisions may not make sense from the broader perspective of food security. Second, the framework used for valuing land in land-use decisions generally recognises only private, direct-use values. If indirect-use and non-use values were brought into the equation, the decision might look different.

Ecosystems: Ecosystems (*e.g.*, forests [as opposed to trees]; oceans, lakes and rivers [as opposed to the fish in them]) provide flows of unpriced services that are used by humans in a variety of ways. The waste assimilation services of rivers, for example, are used by industries and households alike to absorb waste products that would otherwise have to be disposed of by another means at a cost. Ecosystems are subject to both quantitative depletion through human activities (*e.g.*, the conversion of forests into urban land) and to qualitative degradation *via* the same mechanisms just mentioned for renewable resources.

The treatment of ecosystems as capital is the most difficult of the three forms of natural capital. In theory, the correct approach is to observe the services that are provided by ecosystems and to estimate the benefits that these services provide to humans. A list of the major services provided by ecosystems would include cleansing of fouled air and water; the provision of productive soil; the provision of biodiversity; the provision of a predictable and relatively stable climate; the protection from incident solar radiation; and the provision of reliable flows of renewable natural resources.

Even if we can identify what the major ecosystem services are, we cannot observe them directly, just as we cannot observe the transportation service that an automobile provides. In the latter case, economic theory suggests that the discounted value of the services rendered by the automobile over its life is equivalent to the price established for it in transactions between buyers and sellers in a free market. While this theory is useful in understanding the valuation of produced capital goods, it is of little practical value in measuring ecosystems that are not bought and sold.

One possible approach to measuring ecosystems is to consider the quality of their service *outcomes*. The list of major ecosystem services given above translates naturally into a list of outcomes that are more or less observable and that could be used as the basis for measuring ecosystems as capital. For example, the service of waste assimilation has a corresponding outcome of clean air and water. If the outcomes of ecosystems services are constant over time (*e.g.*, air quality does not decline) then one can conclude that the natural capital – that is, the ecosystems – that provide these outcomes are intact. Obviously, the measurement of ecosystem service outcomes is by no means straightforward. Nevertheless, it is argued here that it offers a proxy for ecosystem services that is practically applicable.

Substitution of natural capital

Fundamental to the capital approach is the notion that different forms of capital are substitutable with one another. According to the theory, natural capital should be replaceable with either produced or human capital in any particular human endeavour without reducing the welfare the activity yields. There is diverging opinion on the extent to which this is actually the case. In one school of thought, the possibilities for substituting natural capital with other forms of capital are indeed assumed to be very great if not limitless. In another, they are assumed to be limited to specific cases. The implications of these two viewpoints for the way in which natural capital is measured are great.

If the possibilities for replacing natural capital with other forms of capital are essentially limitless then there is a compelling need to measure natural capital commensurably with produced and human capital. Only when all forms of capital are measured using the same yardstick is it possible to meaningfully compare welfare trade-offs when one form of capital is used in place of another. For all practical purposes, the only common yardstick available for this purpose is money. A sustainable development information system founded on this interpretation of the capital approach would require that all natural capital be measured in monetary terms. This would be problematic in practice, as monetary valuation of the environment is an underdeveloped field. Many forms of natural capital can not be credibly valued given existing methods.

The opposite viewpoint is that the possibilities for substitution of natural capital are limited. Many forms of produced and human capital are seen to be of value only when combined with natural capital; for example, a fishing fleet is essentially worthless unless combined with healthy fish stocks to exploit. Other forms of natural capital are seen to provide services essential to human welfare for which there exist no known substitutes. Examples of this type are few. Global atmospheric systems that provide protection from solar radiation and climate regulation are two. True wilderness, with its matchless psychic value, is another.

The position taken here is that possibilities for the substitution of natural capital are significant but not unlimited. They range from a very high degree of substitutability for traditional natural resources (minerals, metals and fuels) to effectively no substitutability for global systems like the atmosphere.

That substitution of traditional natural resources is possible is readily demonstrated clearly by the many instances in which human ingenuity has arrived at means of making better use of, or even eliminating the need for, certain natural resources. A sawmill is a simple example. Much more efficient use of timber is made if it is cut with a blade than with an axe and, so, sawmills allow more production from the same amount of wood. In other instances, technology has allowed substitution of a relatively rare form of natural capital with one that is superabundant. Fibre optic cable has replaced much of the copper wire that used to be required for communications cables, to cite a popular example.

Of course, there is no certainty that the past will be a reliable guide to the future, but the historical record does give reason to believe that humans will continue to find means of substituting traditional natural resources with produced or human capital. This implies the need to measure these resources in monetary terms, as well as in physical terms, so that the welfare implications of their drawing down can be compared against increases in other forms of capital.

At the other end of the substitution spectrum are examples of natural capital for which no substitute has been found or is likely to be found. As already mentioned, these are relatively few in number but extraordinarily important in contributing to human welfare. The best examples are global atmospheric systems that control climate and regulate radiation reaching the earth. We know of no way of directly substituting for these systems; sunscreen is at best a *partial* substitute for *some* of the services of the ozone layer. If their functioning is reduced, the best we can do is hope to adapt to the changes. Since the loss of irreplaceable forms of natural capital leads inevitably to welfare declines, sustainability demands that such losses be minimized.

Measurement of irreplaceable environmental assets is best undertaken in physical terms. Monetary valuation is not necessary since they are not substitutable by other forms of capital and, therefore, there is no reason to want to directly compare stocks of these assets with stocks of produced or human capital assets. Stocks of irreplaceable natural capital assets must be evaluated in and of themselves.

Factors that affect natural capital

To this point, the discussion has focused on what natural capital is and how it relates to other forms of capital. A fuller treatment of the factors that influence the availability of natural capital is required to complete the discussion and point the way to operationalisation of the approach.

To begin with, it is important to recognize that natural capital is affected by both natural and human processes. Each has the ability to both augment natural capital and cause its decline. Natural processes were, of course, responsible for the creation of natural capital in the first place and it is natural processes that ensure the growth of renewable resources and the functioning of ecosystems. Natural processes are also responsible for the loss of certain forms of natural capital; for example, pest infestations can reduce the quality and quantity of trees across large tracts of forests. An information system founded upon capital would certainly want to measure the impact of such events on environmental assets, even though the events are largely out of the control of humans.

Of much greater interest from a policy perspective are the impacts of human activities, as it is here that the control levers are mainly found. As noted earlier, human activities affect natural capital either through depletion or degradation. Depletion is the result of natural resource exploitation and land use change. Degradation can also be the result of resource exploitation and land use change, but also, importantly, of the introduction of waste products into the environment. Each of these processes is discussed briefly below.

Exploitation of non-renewable resources: By definition, stocks of non-renewable resources are finite and any use of them today necessarily reduces the amount available for use tomorrow. The practical consequences of such depletion are not so straightforward however. First, not all non-renewable natural resource stocks are known. Thus, when we compare depletion against stocks to calculate reserve lifetimes, we are comparing it against only that portion of the theoretically available stock that we actually know to exist. Of course, known stocks are subject to change – sometimes dramatic change – as a result of exploration activity. Thus, the theoretically appropriate depletion concept is one net of new discoveries.

Second, some non-renewable resources are superabundant even if strictly speaking finite; sand and gravel is an excellent example. Economic theory says that these resources derive value mainly from their location rent; that is, the value attributable to them from their proximity to a source of demand. Distant stocks of such resources have no value. Other non-renewable resources that are not superabundant may nevertheless be sufficiently abundant that, in theory, their use today need not preclude any foreseeable future use. Some would argue that many metallic ores are in this category and that any future demand for these ores will be met simply by devising means of extracting deeper reserves.

The final complicating factor with respect to depletion of non-renewable resources is that not all resources are gone forever once they are extracted and used in the economy. Specifically, it is possible in theory to reuse metals an infinite number of times through recycling. Of course, in practice some use of metals is dissipative and leads to irrecoverable losses, so complete recycling is never possible. Nonetheless, it is wrong to consider the stock of metal available for the future as just that found in underground ore; the "above-ground inventory" has to be considered as well. In the case of non-renewable energy resources, this is not at all true and all use leads to irreversible loss of the high grade, stored energy.

Exploitation of renewable resources: Exploitation of renewable resources need not lead to losses in natural capital provided that the rate of exploitation is equal to or less than the rate of natural growth. While true in a logical sense, this commonly accepted notion neglects the tension between renewable resources as inventories of raw material and the same resources as integral parts of functioning ecosystems. Old growth forest, for example, can be viewed as an extremely valuable source of high grade timber or as a special type of forest ecosystem offering very significant indirect-use and non-use benefits. To a large extent, realising the value of old-growth forests as raw material sources precludes realising any value as unique ecosystems and *vice versa*. An information system founded on capital would want to provide information relevant to evaluating old growth forests from both of these perspectives.

Even in the case where exploitation of a renewable resource does not lead to any quantifiable change in the size of the stock, there may well be qualitative changes that will affect its value as natural capital. For example, when a mature timber tract is clear-cut it is normally the case that nature will, left to its own devices, restock the land with trees. However, the natural way of things is such that the replacement trees will be of a different species than those that were cut. So-called "transitional species" will tend to dominate in the early years. These may be of lower value as natural capital for a variety of reasons: they may be less valued as material inputs; they may be less rich in terms of supporting biodiversity; or they may be less attractive from an aesthetic perspective. Only after many decades, or even centuries, will the forest begin to resemble that which it replaced. Given that the average rotation age for cutting in managed forests is less than 100 years, once mature timber tracts are cut, we may never again see them as they would exist in their undisturbed state.

Land-use change: Land-use change refers to human-induced changes in the functions that land areas are allowed to fulfil. It normally involves physical restructuring of the land surface in some way; for example, through removal of vegetation, soil or rock; modification of slope; or damming of waterways to create reservoirs. As noted above, land area itself cannot be depleted or degraded in the same way as other forms of natural capital. However, land-use change does lead to increases and decreases in specific categories of land. An increase in land used for urban purposes can only come at the expense of land used previously for some other end. Equally importantly, land-use change can lead to degradation of other forms of natural capital (particularly ecosystems). The construction of transportation corridors can disrupt wildlife habitat and breeding patterns, for example.

Emission of wastes: The final and most complex way in which human activity impacts natural capital is through the emission of wastes.[6] The impact of wastes is mainly felt in terms of degradation in the capacity of ecosystems to provide the service outcomes we rely upon. Excessive introduction of wastes can, for example, overcome the assimilative capacity of the environment and reduce its supply of clean air and water.

Understanding the relationship between waste emissions and the degradation of natural capital is extremely complex. There is no explicit guidance offered on this point in capital theory. It is properly the domain of the environmental sciences and this speaks to the need to engage scientists in identifying the most important waste emissions to measure in a sustainable development information system. Although some wastes are obvious, others may not be.

From a policy perspective, waste emissions represent important levers of control and, therefore, it would be imperative that the information system measure them as fully as possible. Of great importance would be linking waste emissions data with data from economic information systems so that the full force of our economic understanding can be brought to bear in studying the costs and benefits of reducing waste emissions.

Operationalising the approach – A proposed set of environmental accounts

The foregoing has laid out the conceptual framework for a sustainable development information system based on capital with a particular focus on the environmental component of the system. It is now a relatively simple matter to describe a system of accounts that could be used to operationalise the approach. Such a system has been proposed recently by Statistics Canada as the basis for a national set of environmental and sustainable development indicators.[7] It comprises three broad components: Natural Capital Asset Accounts, Material and Energy Flow Accounts and Environmental Protection Accounts.[8]

The accounts described below do not represent Statistics Canada's first foray into the field of environmental accounting. Indeed, a limited version of this system of accounts has been produced on an occasional basis since 1997.[9] Those familiar with the recently revised UN handbook on integrated environmental and economic accounting (commonly

6. Wastes in this context include all gaseous, solid and liquid materials rejected into the environment from human activity.

7. For a discussion of the process that led to the development of this proposal see Smith, Robert B., 2003, "The Role of Institutions in Building Frameworks to Measure Sustainable Development: The Canadian Experience", also prepared for the OECD meeting on Accounting Frameworks to Measure Sustainable Development, Paris, 14-16 May, 2003.

8. Additional details on this proposed set of accounts are available from the author.

9. See Statistics Canada, 2000, Econnections: Linking the Environment and the Economy – Indicators and Detailed Statistics 2000, Catalogue No. 16-200-XKE, Ottawa, and Statistics Canada, 1997, Econnections: Linking the Environment and the Economy – Concepts, Sources and Methods of the Canadian System of Resource and Environmental Accounts, Catalogue No. 16-505-GPE, Ottawa.

known as the SEEA)[10] will note that the system corresponds closely to the accounting framework of the SEEA.

Natural Capital Asset Accounts

The proposed Natural Capital Asset Accounts will provide estimates of Canada's key natural capital stocks (natural resources, land and ecosystems) and the annual changes in these stocks due to natural and human processes. These accounts will in all instances present physical estimates of the extent and quality of natural capital. In addition, to the degree possible, stock estimates will be presented in monetary terms so that they are directly comparable with the estimates for other forms of capital included in the national accounts. The accounts will be compiled at a minimum at the national level; where appropriate, sub-national estimates will also be presented using ecologically and politically defined spatial units.

The Natural Capital Asset Accounts will form the basis for the estimation of several new macro aggregates. Most importantly, they will be the source of the estimates of the value of natural capital that will be included in an expanded estimate of national wealth. In addition, a variety of aggregate measures in physical terms will be possible, including, for example, life length of remaining proven energy and mineral reserves, ratio of remaining proven reserves to total reserves, ratio of harvested forest area to total forest area, and so on. These aggregate measures will reveal the extent to which stocks of natural capital are being depleted (or not) in the course of economic development.

The Natural Capital Asset Accounts will comprise 1) Subsoil Asset Accounts, 2) Biological Resource Asset Accounts, 3) Land and Terrestrial Ecosystem Asset Accounts, 4) Water and Aquatic Ecosystem Asset Accounts, and 5) Atmospheric Asset Accounts. Each of these is described briefly in the Annex to this document.

Material and Energy Flow Accounts

The proposed Material and Energy Flow Accounts will describe the annual flows of materials and energy between the Canadian environment and economy and within the Canadian economy itself. In addition, flows between the Canadian environment and the rest of the world economy and environment will be tracked. Such flows will include intentional imports and exports of materials and energy as well as unintentional transboundary movements of materials in air and water currents. These accounts will be measured in all cases in physical units and, where possible, in monetary terms as well. They will be compiled at the national and provincial levels at a minimum and, where possible, sub-national estimates will also be presented using ecologically defined units. For a limited number of highly important material flows (for example, energy and greenhouse gas flows) accounts will be compiled on a quarterly basis.

The Material and Energy Flow Accounts will be structured using the same detailed classification of producers, commodities and consumers found in the Input-Output Accounts. In this way, the data on material and energy flows will be easily combined with the corresponding economic data on production and consumption. Based on this combination, indicators will be calculated describing the extent to which the economy

10. United Nations, European Commission, International Monetary Fund, Organisation for Economic Co-operation and Development and World Bank, 2003, *Integrated Environmental and Economic Accounting 2003*, ST/ESA/STAT/SER.F/61/Rev.1 (Final draft), New York: United Nations (http://unstats.un.org/unsd/environment/seea2003.pdf).

exerts demands on the environment as a source of raw materials and as a sink for waste materials. This combination of economic and environmental data has substantial potential for the study of dematerialisation (that is, the de-coupling of economic growth with growth in the throughput of material and energy), a goal which is considered by many as a cornerstone of sustainable development.

The Material and Energy Flow Accounts will comprise 1) Energy Flow Accounts, 2) Raw Material Flow Accounts, 3) Recycled Material Flow Accounts, 4) Water Use Accounts, 5) Greenhouse Gas Emission Accounts, 6) Air Pollutant Emission Accounts, 7) Water Pollutant Emission Accounts, and 8) Solid Waste Emission Accounts. Each is described briefly in the Annex.

Environmental Protection Accounts

The proposed Environmental Protection Accounts will show the transactions within the economy that are concerned with protecting, improving and managing the environment by business, government, households (including individuals) and trade with the "rest of the world." The accounts will provide statistical information on society's response to environmental problems in terms of expenditures and revenues related to protecting the environment. In addition, the production and consumption of environmental goods and services will be tracked. These accounts will be measured in all cases in monetary units and updated annually. They will be compiled at the national and provincial/territorial levels[11] at a minimum; where appropriate, sub-national estimates will also be presented using ecologically defined units.

The Environmental Protection Accounts will comprise 1) Environmental Revenue and Expenditure Accounts, and 2) Supply and Use Accounts for Environmental Goods and Services. Again, each is described briefly in the Annex.

Conclusion

An argument has been set forth for the adoption of a capital approach as the foundation for a sustainable development information system. A number of its advantages have been outlined, the conceptual framework has been described in detail as it applies to the environment and it has been shown to be operationalisable in a system of accounts. In the author's opinion, the approach offers the greatest promise for creating robust, policy-relevant information for sustainable development.

At the same time, questions inevitably remain in such a new field. A few of the more urgent and interesting are noted below.

Given the need to measure many forms of capital using money as the yardstick, additional work to develop valuation techniques is urgently required. At the moment, only a fraction of the environmental assets that should be measured in monetary terms can be monetized with existing techniques. As a starting point, research on the valuation of fisheries, water, recreational land use and environmental waste assimilation services is required.

The question of substitution deserves more careful attention. It has been argued here that some environmental assets provide essential and irreplaceable services and,

11. Canada is a federation comprising 10 provinces and 3 territories. Control over natural resource management and environmental quality rests largely with the provincial and territorial governments.

therefore, ought not to be considered substitutable. Many would disagree. To better reveal the nature of this disagreement and attempt to resolve it, a fuller exploration of ecosystem services and the interpretation of "substitution" in the context of these unpriced and, sometimes, unrevealed flows would be helpful.

Finally, the ethical foundation of the capital approach offers a rich set of issues for debate. Many would find the strongly anthropocentric perspective of the approach indefensible. The notion that environmental assets have value only, or even mainly, because of the services they provide for humans would be rejected from almost any other perspective. Certainly, most true environmentalists would find it unacceptable. Yet there is not necessarily a wide gulf between the anthropocentric and eco-centric moral views when it comes to the need to preserve environmental services. It is possible from both perspectives, albeit by different routes, to conclude that fundamental environmental services must be preserved. The possibilities for such convergence are worthy of further exploration.

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