Statistics Canada - Natural Resource Reserve Index

Abstract

Statistics Canada compiles natural resource asset accounts, which currently include selected natural resources where data is available, such as oil, gas, and gold, as well as timber. These accounts provide an estimate of Canada's resource wealth, an important contributor to the country's economy. Natural resource wealth is highly volatile, primarily due to fluctuations in resource prices, but also because of changes in reserves. Thus, it is inherently volatile as it embodies highly unpredictable factors such as resource prices, extraction costs and resource rent.

The physical reserve of a resource which is the basis of the wealth, also occasionally undergoes changes due to extraction, technological advancement and discoveries or re-evaluations of resource stocks. Price-induced volatility in natural resource wealth is well-established, however the impact of changes in physical reserves on wealth is seldom studied[1].

Currently the System of Environmental-Economic Accounting 2012: Central Framework (SEEA-CF) discusses physical and monetary asset accounts (section 5.3), both volatile measures which the natural resource reserve index (NRRI) aims to rectify. Statistics Canada does not currently publish an NRRI but aims to do so in the near future.

The number of studies on NRRI is limited to a few examples, such as Australia, New Zealand and the Netherlands. The approaches taken by the three countries are quite different and serve different purposes. The Australian Bureau of Statistics index measures constant price of monetary assets for their inclusion in the national balance sheet accounts, but does not aggregate physical reserves[2]. The New Zealand statistical agency tracked the relationship between resource use and growth in production, consumption and population using decoupling indicators[3]. The Netherlands' approach is based on a pre-defined scale and examines the state of ecosystems[4]. In this article Canada proposes to compute a NRRI and link it with monetary wealth.

The proposed index is created by averaging physical reserves weighted by their relative share of wealth. Simply adding reserves of different resources is not possible since for instance, oil is measured in cubic metres and gold is measured in tonnes. The chain-Fisher index, with 1990 as the base year, tracks the physical dimension of reserves over time and enhances interpretation of

[1] As discussed by Alan Gelb, Kai Kaiser, and Lorena Vinuela in *How Much does Natural Resource Extraction Really Diminish National Wealth*.
[2] The methodology used by the Australian Bureau of Statistics was introduced in 2001, and has since been updated as of 2015. A more detailed description of the updated methods can be found in Section III.
[3] This methodology is used by Stats NZ Tatauranga Aotearoa as of April 2017.
[4] This methodology is used by the Netherlands as of 2000.

monetary wealth. Findings reveal that natural wealth moved in tandem with the NRRI in most years, however the two occasionally diverted.

The NRRI would:

- track year-over-year change in aggregate natural resource stock
- identify which category of resources is depleting faster than it is being replaced
- analyze the wealth volatility stemming from changes in reserves.

A comprehensive understanding of natural resource assets would be enhanced by a reserve index. Furthermore, such an index, in conjunction with human capital and produced capital, can be used as an indicator of sustainable development and help design sustainable development strategies. This topic will be discussed in greater detail in Section IV. . It is recommended that a section be added to the SEEA CF that outlines the concepts and methodology of the NRRI. Canada proposes adding section “5.3.4 Conceptual form of the natural resource reserve index.”

I. Introduction

Statistics Canada is considering the addition of a natural resource reserve index (NRRI) to the System of Economic and Environmental Accounting (SEEA) to complement its annual Natural Resource Asset Accounts (NRAA). Natural capital consists of ecosystems, land and sub-soil resources[5]. Commonly, natural capital is used to refer to all types of environmental assets as defined in the SEEA Central Framework[6], along with the services they provide. The index is intended to act as an indicator of sustainable development by incorporating the natural resources (sub-soil resources and timber) aspect of natural capital. The concept of sustainable development[7] is supported by the three pillars: environment, social, and economic. As a result, the index can then be used to design sustainable development strategies complemented by indicators on human and produced capital. Depending on data availability, the index can also be produced at the provincial/territorial level.

This paper presents a NRRI that can track year-over-year change in aggregate natural resource stock; identify which category of resources is depleting faster than it is being replenished[8], and analyze the wealth volatility stemming from changes in reserves.

The rest of the paper is organized into sections as follows:

- Section II discusses Canada's status;
- Section III briefly reviews similar studies;
- Section IV outlines the methodology of the index formula;
- Section V discusses the findings;
- Section VI links the reserve index with sustainable development;
- Section VII discusses the limitations of the index;
- Section VIII discusses the findings of the index;
- Section IX provides concluding remarks.

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[5] According to the Natural Capital Declaration launched at the 2012 UN Conference on Sustainable Development, Natural capital comprises Earth's natural assets (soil, air, water, flora and fauna), and the ecosystem services resulting from them.

[6] The SEEA uses the terms environmental assets and natural resources, rather than natural capital. It provides for transaction accounts covering environmental protection spending, making it more observable than in the standard SNA accounts.

[7] Sustainable development refers to the development that meets the needs of the present without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development, Brundtland Commission), 1987, Our Common Future, Oxford University Press, Oxford, United Kingdom).

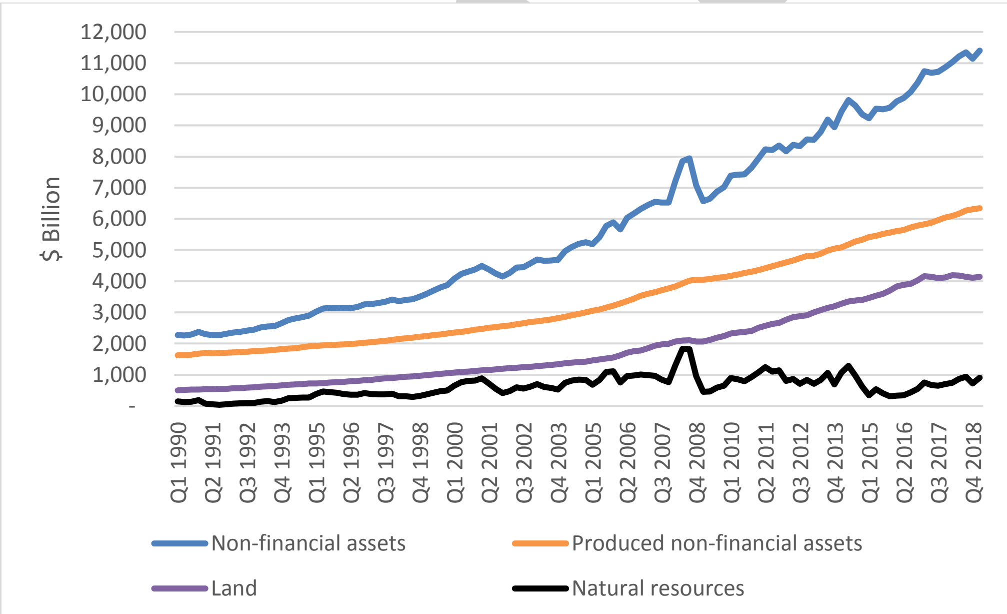
[8] Although extraction depletes the absolute amount of a non-renewable resource, economically recoverable reserves can be replenished or even augmented through discoveries.

II. Status

Statistics Canada currently publishes an annual physical and monetary account of natural resources in Canada which adheres to the international standard outlined in the SEEA. The natural resources included in the accounts are selected on data availability and include energy, selected minerals and timber. Energy resources are comprised of coal, crude oil, crude bitumen, and natural gas while mineral resources consist of gold, iron, copper, nickel, molybdenum, uranium, lead, potash, and diamonds. Timber commodities are only included in the monetary account[9] because of a lack of timber stock data[10]. Statistics Canada also publishes natural resources quarterly in the National Balance Sheet (NBS). The inclusion of the NRAA in the NBS reflects a more complete picture of Canada's wealth.

The SNA 2008 (the latest version of the United Nations System of National Accounts) recommended the inclusion of natural resource assets (NRA)—the *in situ* value of remaining resource stocks—in the national balance sheet accounts (NBSA). The SNA 2008, however, did not provide clear guidance on partitioning NRA between the government and corporations.[11] Therefore, Statistics Canada developed a method of generating quarterly sectored NRA, and has formally integrated NRA with land and produced assets in the NBSA.[12]

Chart 1: Non-financial assets, 1990Q1 to 2019Q1



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[9] For details, see SNA 2008 10.167 https://unstats.un.org/unsd/nationalaccount/docs/SNA2008.pdf

[10] The wealth estimate is based on the assumption that the stock will remain the same for an indefinite period. Once available, timber stock data could be added to broaden the volume index.

[11] For details, see, http://www.statcan.gc.ca/pub/13-605-x/2015009/article/14239-eng.htm

[12] For details, see, Natural resource wealth statistics in the National Balance Sheet Accounts: http://www.statcan.gc.ca/daily-quotidien/151214/dq151214a-eng.htm?HPA

Source: Statistics Canada, table 36-10-0580-01.

In the fourth quarter of 2015, owing to a drop in energy resource prices, the value of natural resource assets declined 22% (Chart 1). Since 1990, both land[13] and produced assets[14] have grown steadily, whereas the NRA has been highly volatile. In the third quarter of 2008, for instance, natural resource wealth reached its peak (+$1,823 billion) due to record-high oil prices and increased energy resource reserves; in the next two quarters, the wealth plummeted because of the sharp drop in resource prices in the wake of the 2008 global financial crisis. Although this volatility mainly stems from fluctuating resource prices, changes in physical stocks also play a crucial role.[15]

The total stock of a non-renewable resource is assumed to be fixed, however the actual quantity is largely unknown. Using a set of economic and geological criteria, Natural Resources Canada identifies mineral resource reserves under several categories: proven and probable, indicated and measured, and speculative and hypothetical.[16] Statistics Canada assigns a monetary value to the proven and probable category of mineral resources, as the likelihood of their existence and extraction is 90% or higher. For a similar reason, a monetary value is assigned to the established reserves of oil and gas; these reserve classes change with additions to reserves, deletions from reserves, and production.[17] More importantly, these factors vary across resources—in a given period, oil reserves may rise and gold reserves may fall.

[13]Only developed land (used in farming, building houses and buildings) is included for wealth estimation. As time passes, typically both the area and price go up, and therefore, the land asset rise.

[14]Produced assets are comprised of residential structures, non-residential structures, machinery and equipment, intellectual property products, consumer durables, inventories, and weapons systems.

[15]The data and definitions of physical reserves can be accessed through the Canadian System of Environmental and Resource Accounts - Natural Resource Asset Accounts <http://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=5114, accessed April 25, 2016>.

[16]Natural Resource Canada uses a generalized model to categorize reserves based on economic feasibility as well as geological probability. For details, see, http://www.nrcan-rncan.gc.ca/mms-smm/busi-indu/cmy-amc/content/1996/03.pdf , accessed January 5, 2016

[17]The additions and deletions to reserves are the result of new discoveries, new geological information, technological change, resource price, and change in extraction costs. For details, see, http://www.nrcan.gc.ca/miing-materials/exploration/8294

Chart 2: Established crude bitumen reserves, 1990 to 2016

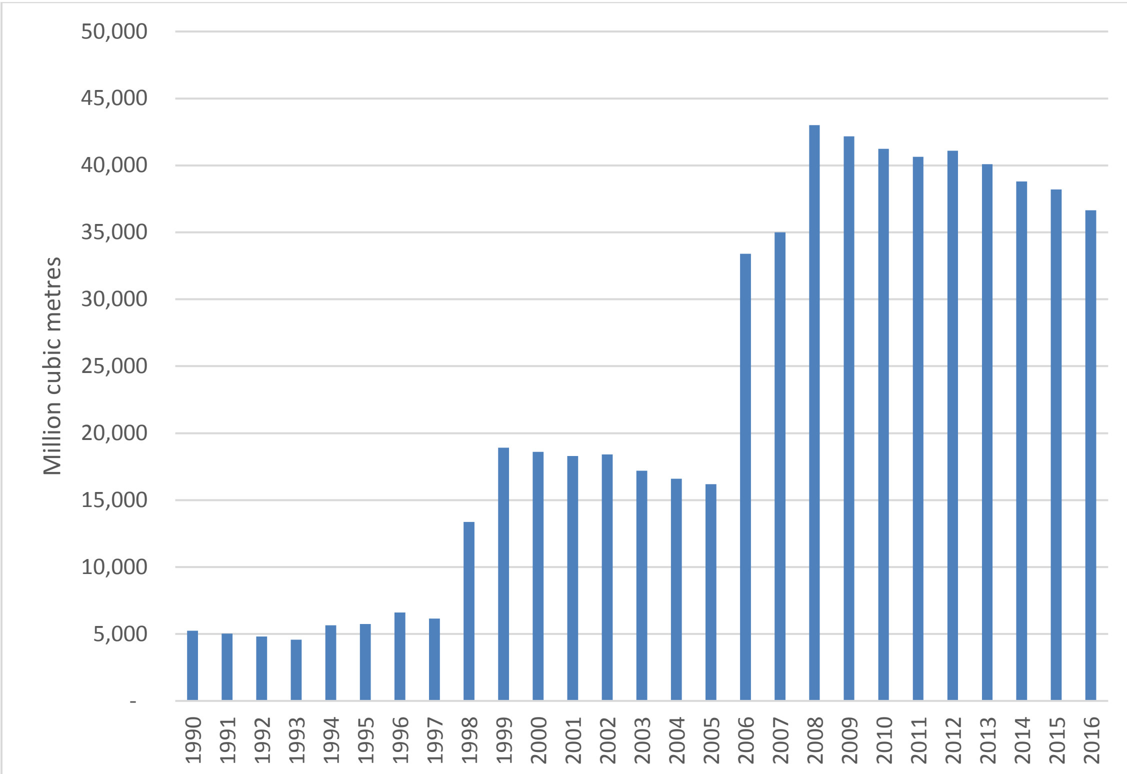
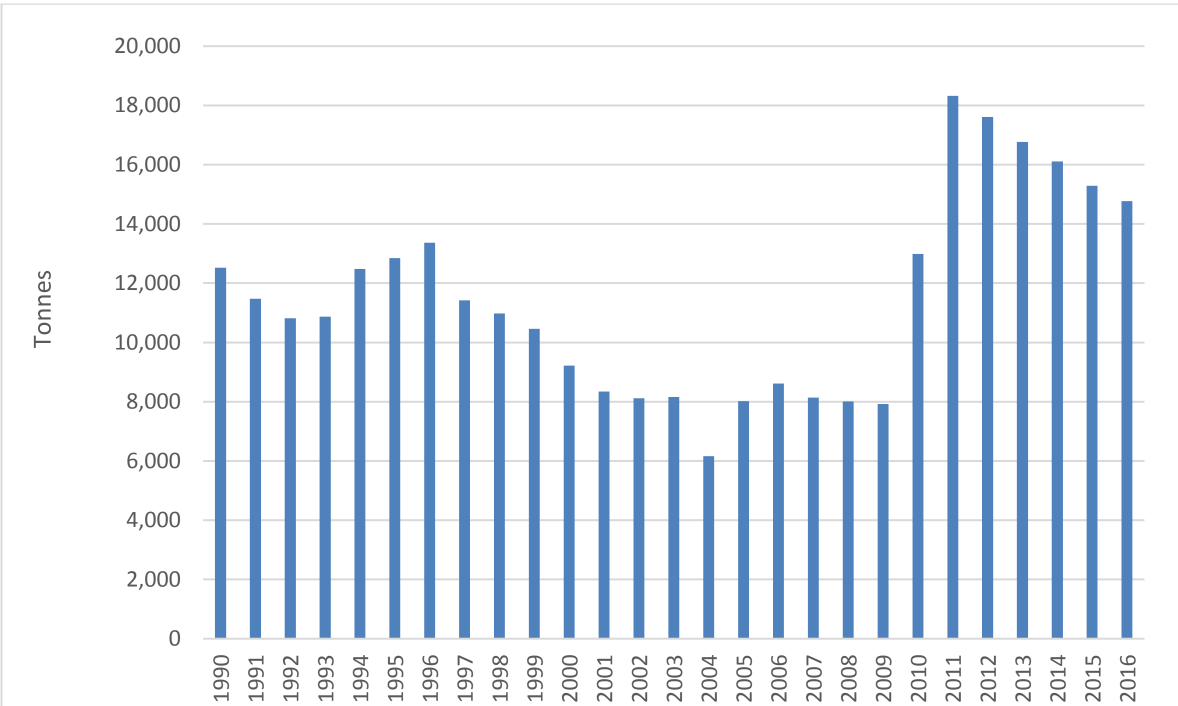


Chart 3: Proven and probable gold reserves, 1990 to 2016



Source: Statistics Canada, table 38-10-0007-01.

In 2008, for instance, crude bitumen reserves increased 22%, but gold reserves dropped 4% (Charts 2 and 3). By looking at the stock of each resource individually, it is almost impossible to assess the overall stock of both resources together, as the former is measured in cubic metres, and the latter in tonnes. Even if two or more resources are measured in the same unit, their physical stocks cannot be meaningfully added because their relative values vary. In fact, the wealth estimate recorded in the NBSA stems from 14 different natural resources that fall under three categories—energy resources, mineral resources[18], and timber. Thus, a meaningful aggregation is essential to obtain a snapshot of physical stocks.

[18]Some minerals are mined as by-products—silver from gold mines, zinc from lead and copper mines—but their physical stocks and monetary values are relatively insignificant.

III. Previous studies – Background

The number of studies on natural resource index is limited. In 2001, the Australian Bureau of Statistics (ABS) introduced an experimental national balance sheet that excluded the effects of price change.[19] The constant price balance sheet was used to evaluate the composition of non-financial assets over time and to construct an index of real growth of different assets in the balance sheet. Currently, the ABS derives chained volume estimates for mineral and energy resources and timber by using explicit price and volume in combination with constant unit resource rents and discount rates to more accurately capture the impact of volume changes.[20]

Primarily to evaluate the state of ecosystems, the Netherlands created a set of natural capital indicators based on a 0-to-100 scale that incorporated both the size and quality of ecosystems: 0 means that the entire ecosystem has deteriorated because no area is left, or the quality is 0, or both; 100 implies that the entire ecosystem is intact and is at its maximum value.[21]

In New Zealand, decoupling indicators derived by comparing population growth with a relative physical flow identify the divergence between environmental and economic aggregates. By tracking the relationship between the total level of electricity generation and population growth from 2007 to 2015, estimates expressed that fewer energy resources in the form of electricity were being demanded per person, implying greater efficiency in energy resource use[22].

The approaches taken by the three countries are quite different and serve different purposes. The ABS index measures constant price monetary assets for their inclusion in the national balance sheet accounts, but does not aggregate physical reserves. The Netherlands approach, based on a pre-defined scale, examines the state of ecosystems. The New Zealand method focuses on selected environmental asset, i.e. electricity generation. This paper presents a detailed version of previous work by the author,[23] on the computation of a NRRI for Canada and links it with monetary wealth.

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[19]For details, see *Developments in Australian Wealth Statistics*, 30th Annual Conference of Economists, Perth, Australian Bureau of Statistics, 2001.

[20] For details, see *Australian System of National Accounts – Concepts, Sources and Methods*, Perth, Australian Bureau of Statistics, 2015.

[21]For details, see *Towards a Method to Estimate Critical Natural Capital*, Discussion Paper for the second meeting of the CRITINC-project, Netherlands, Wageningen University & Research Centre, Department of Environmental Sciences, 2000.

[22] For details, see *Asset value of water and other renewables for electricity generation: 2007 15*, Stats NZ, Tatauranga Aoteraoa, 2017.

[23]*For details, see*, http://www.statcan.gc.ca/pub/16-002-x/2007003/10454-eng.htm#footnote2, *accessed, February 29, 2016.*

IV. Methodology

A wide variety of index number formulas with a sound micro-economic underpinning are regularly used to track prices and volumes[24] of goods and services. These formulas, essentially weighted averages, primarily differ in the weights assigned to calculate them. As such, the NRRI is calculated using Laspeyres, Paasche, and Fisher formulas, a brief description of which follows.[25]

A. Laspeyres volume index

For the Laspeyres volume index, a pre-selected base year's prices are used as weights; the formula can be written as:

$$Q^L = \frac{\sum_{i=1}^{n} q_t^i p_0^i}{\sum_{i=1}^{n} q_0^i p_0^i} \cdots\cdots\cdots\cdots 1$$

where

Q^L = the Laspeyres volume index for the period t using the base period 0,
p = the price series
q = the quantity series
i = refers to the ith item, and n is the total number of items.
For simplicity, 'i' would be dropped from here on.

Formula 1 can be used to calculate a fixed-base Laspeyres volume index; hypothetical examples of volume indices are provided at the end of this section. Since natural resource data are available in 'q' and 'V' forms (q=physical reserves, and V=value of reserves), the above formula can be expressed as:

$$Q^L = \frac{\sum q_t p_0}{\sum q_0 p_0} = \frac{\sum \left[\frac{q_t}{q_0}\right] q_0 p_0}{\sum q_0 p_0} = \frac{\sum \left[\frac{q_t}{q_0}\right] V_0}{\sum V_0} \cdots\cdots 2$$

where V_0 = value of the resource reserve in the base year

A volume index calculated using formula 2 is easy to interpret and additive—if separate indexes are calculated for mineral and energy resource reserves, they can be summed to obtain the aggregate reserve index. However, the formula is highly dependent on selection of the base year.

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[24]Volume index, used in this paper, is essentially a quantity index. The volume index is widely used in national accounting to take into account qualitative changes of goods and services; for instance, price adjusted GDP reflects underlying changes in physical quantity and quality of the goods and services.

[25]For details, see, Allen, R.G.D. 1975, Index Numbers in Theory and Practice, Aldine Publishing Company, Chicago.

A more appropriate version is the chained Laspeyres index, which uses weights based on the preceding period rather than on a fixed base year. To calculate a chained index, the year-over-year index, also known as the unchained index, must first be estimated. The unchained or unlinked index is essentially an ordinary fixed-base Laspeyres index calculated for just two consecutive periods:

$$Q_{t/t-1}^{UCL} = \frac{\sum q_t p_{t-1}}{\sum q_{t-1} p_{t-1}} = \frac{\sum \left[\frac{q_t}{q_{t-1}}\right] q_{t-1} p_{t-1}}{\sum q_{t-1} p_{t-1}} = \frac{\sum \left[\frac{q_t}{q_{t-1}}\right] V_{t-1}}{\sum V_{t-1}} \cdots\cdots\cdots\cdots 3$$

Formula 3 provides Laspeyres volume index reflecting change in two consecutive periods, and the cumulative change is measured by chaining them using a reference year:

$$Q_{t/1}^{CL} = 1 \times \left(Q^{UCL}\right)_{period2} \times \left(Q^{UCL}\right)_{period3} \cdots \left(Q^{UCL}\right)_{periodt}$$
$$= \prod_{y=1}^{t} Q_{y/y-1}^{UCL} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots 4$$

Formula 4, the chained Laspeyres index, is simply the product of unchained indexes, where the index for the reference period is assumed to be 1 or 100. Because of its multiplicative form, it is easy to shift the reference year without losing the trend. The chained Laspeyres index usually provides an upper bound as it applies the previous period's weight.

B. The Paasche volume index

The Paasche volume index applies the final or current year's price as the weight. The formula can be expressed as:

$$Q^P = \frac{\sum q_t p_t}{\sum q_0 p_t} = \frac{\sum q_t p_t}{\sum \left[\frac{q_0}{q_t}\right] q_t p_t} = \frac{\sum V_t}{\sum \left[\frac{q_0}{q_t}\right] V_t} \cdots\cdots 5$$

Where Q^P is the Paasche volume index, and
V_t= Value of the resource stock in period t

Like the Laspeyres index, the unchained and chained versions of the Paasche index can be expressed as:

$$Q_{t/t-1}^{UCP} = \frac{\sum q_t p_t}{\sum q_{t-1} p_t} = \frac{\sum q_t p_t}{\sum \left[\frac{q_{t-1}}{q_t}\right] q_t p_t} = \frac{\sum V_t}{\sum \left[\frac{q_{t-1}}{q_t}\right] V_t} \cdots\cdots\cdots\cdots\cdots\cdots 6$$

$$Q_{t/1}^{CP} = \prod_{y=1}^{t} Q_{y/y-1}^{UCP} \cdots\cdots\cdots\cdots 7$$

Although the chained Laspeyres and the chained Paasche indexes are more relevant than the fixed based indexes, none is ideal. If the price relatives (p_t/p_{t-1}) and the quantity relatives (q_t/q_{t-1}) are negatively correlated, the Laspeyres formula generates the upper bound, and the Paasche provides the lower bound. The opposite happens if the price and quantity relatives are positively correlated. To resolve this problem, Irving Fisher proposed an index that takes the geometric mean of these two indexes.

C. The Fisher volume index

The Fisher volume index is the geometric mean of the Laspeyres and Paasche indexes, and can be shown as:

$$Q^F = \sqrt{Q^L \times Q^P} = \sqrt{\frac{\sum\left[\frac{q_t}{q_0}\right]V_0}{\sum V_0} \times \frac{\sum V_t}{\sum\left[\frac{q_0}{q_t}\right]V_t}} \cdots\cdots\cdots\cdots 8$$

or the unchained version

$$Q_{t/t-1}^{UCF} = \sqrt{Q_{t/t-1}^{UCL} \times Q_{t/t-1}^{UCP}} = \sqrt{\frac{\sum\left[\frac{q_t}{q_{t-1}}\right]V_{t-1}}{\sum V_{t-1}} \times \frac{\sum V_t}{\sum\left[\frac{q_{t-1}}{q_t}\right]V_t}} \cdots\cdots\cdots\cdots 9$$

Formula 9 is the square root of unchained Laspeyres and unchained Paasche; the chain Fisher volume index can be written as follows:

$$Q_{t/1}^{CF} = \prod_{y=1}^{t} Q_{y/y-1}^{UCF} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots 10$$

The Fisher formula fulfills the time and factor reversal tests of index numbers—two important criteria for an ideal index formula[26]. The time reversal test requires that if the base and current periods are interchanged, the formula produces the reciprocal of the original index, that is, 1/time-interchanged-index equals the original index. The factor reversal test requires that the product of price and volume indexes will produce the value index: $P_{01}Q_{01}=V_{01}$.

[26] As discussed in Statistics Canada User Guide for the Canadian System of Macroeconomic Accounts on price and volume measures. For details, see https://www150.statcan.gc.ca/n1/pub/13-606-g/2016001/article/14622-eng.htm

The main limitation of the chain Fisher index is its non-additivity—the indexes stemming from components do not sum to the aggregate index. Despite this limitation, the Canadian System of National Accounts applies the chained Fisher index because of its superiority over other indexes. To produce a coherent natural resource reserve index, this paper focuses on the chain Fisher volume index.

Numerical Example of Chain Indexes

Components: The two components of a natural resource reserve index are: q—quantity or physical stock of resources, and V—dollar value of the stock. Statistics Canada compiles the reserve data (q) from various sources including Natural Resources Canada and the Alberta Energy Board. The data on sales revenue and extraction costs are collected through surveys such as the *Annual Census of Mines, Quarries and Sandpits*. Based on these data, the dollar value of a resource reserve is computed.

$$V = \sum_{t=1}^{RL} \left[\frac{R_t}{(1+r)^t} \right]$$

where R= resource rent, that is, the difference between sales revenue and extraction cost
r = discount rate, t = year, and reserve life, RL = stock/production

Computation: Using hypothetical data on q and V, the main steps of calculating chain indexes are discussed.

	Resource A (cubic metres)					Resource B (tonnes)					Laspeyres				Paasche				Fisher
	c2	c3	c4	c5	c6	c7	c8	c9	c10	c11	c12	c13	c14	c15	c16	c17	c18	c19	c20
	q	qt/qt-1	V $	NL	DP	q	qt/qt-1	V $	NL	DP	ΣNL	ΣDL	UCL	Index	ΣNP	ΣDP	UCP	Index	Index
1990	**3**		**21**			**5**		**20**						**100**				**100**	100
1991	4	1.33	24	28	18	6	1.20	30	24	25	52	41	1.27	**127**	54	43	1.26	**126**	126
1992	5	1.25	25	30	20	4	0.67	24	20	36	50	54	0.93	**117**	49	56	0.88	**110**	114

Note: Numbers, rounded for space considerations, should be looked at in conjunction with formulas 1 to 10 noted earlier.

The table provides an example of chain index calculations based on two resources with time series data on reserves and their dollar values: ‘q’ measured in cubic metres in c2 for resource A; ‘q’ measured in tonnes in c7 for resource B; and their ‘V’ in dollars in c4 and c9 respectively for resource A and resource B.

First, the quantity relatives (q_t/q_{t-1}) are calculated—ratios in c3 and c8 for resources A and B respectively. The numerator of the Laspeyres (NL) index is obtained by multiplying these ratios by the corresponding values from the previous period (V_{t-1}); V_{t-1} is the denominator (DL) of this index. By summing numerators and denominators for the two resources, ΣNL and ΣDL are computed. For reference year 1991, for instance, ΣNL is 52 (=28+24 in c5 and c10 respectively) and ΣDL is 41 (=21 + 20 in c4 and c9 for reference year 1990). The unchained Laspeyres (UCL in c14) index in a year is the ratio of ΣNL to ΣDL. Next, it is assumed that the index equals 1, or 100 for 1990. The chained Laspeyres index is the product of unchained indexes; that is, the index in 1991 (=100*1.27) is 127 and in 1992 equals 117 (=127*0.93) as shown in c15.

The numerator of the unchained Paasche (ΣNP) index is derived by summing the values in c4 and c9; and the denominator (ΣDP) is obtained by adding c6 and c11. Similar to the chained Laspeyres index, the chained Paasche index is computed in c19. The chain Fisher index, the square root of chain Laspeyres and chain Paasche, is recorded in c20. The natural resource reserve index applies same techniques for 13 non-renewable resources.

V. Natural resource reserve index findings

As noted earlier, natural assets in the NBSA stem from timber, energy, and mineral resources. The physical stocks of 13 types of energy and mineral resources and their monetary values are applied to estimate Canada's non-renewable NRRI .[27]

Chart 4: Natural resource reserve index, 1990 to 2016

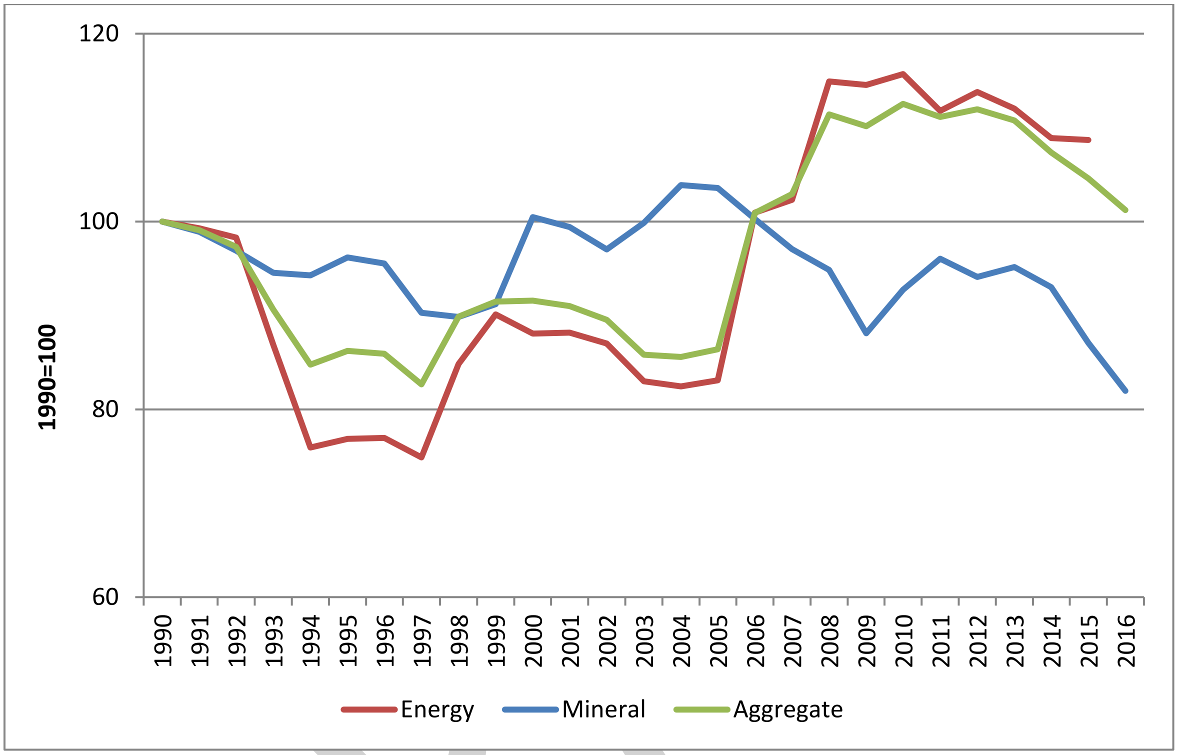


Chart 4 presents the aggregate NRRI and its two major components.[28] In 1993, the aggregate index decreased by 6.8%, as extractions of natural gas and crude bitumen occurred but no new discoveries were made (unless conserved or replenished, the index is expected to fall with ongoing extraction of resources). The index recovered slightly in 1995 only to reach its bottom in 1997, when both energy and mineral indexes declined. In 1998, the NRRI recovered 9%

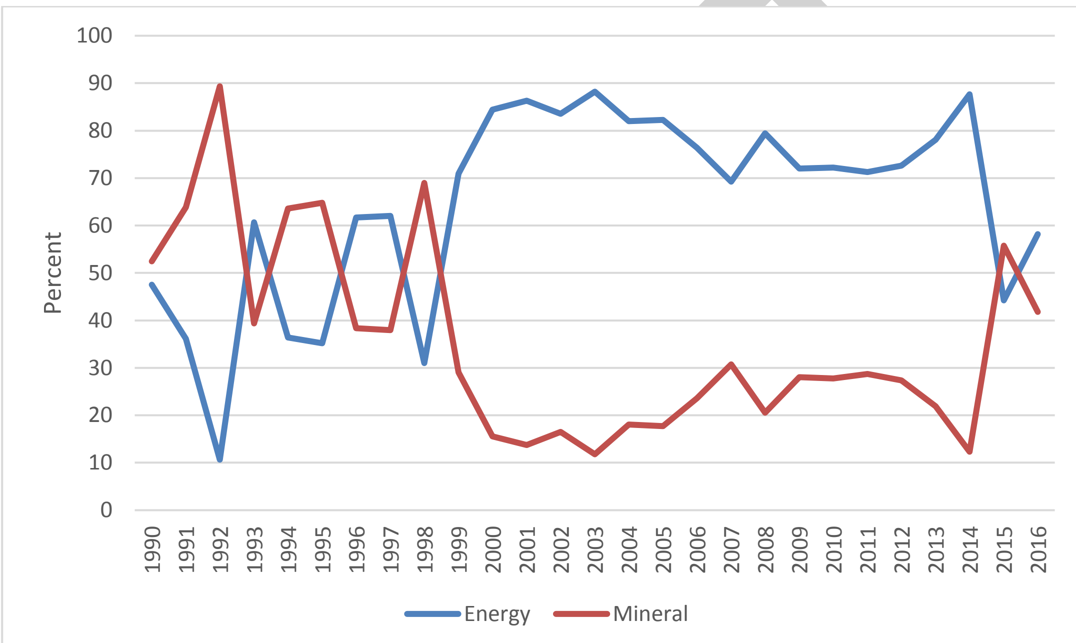
[27]Data on timber stock are not available after reference year 2003. The wealth estimate is based on the assumption that the stock will remain the same for an indefinite period. Once available, timber stock data could be added to broaden the volume index.

[28]As noted earlier, an index constructed by summing the energy index and the mineral index would not be equal to the aggregate index because a chain-Fisher index is non-additive. Nonetheless, the sub-indexes enhance the interpretation of the aggregate index so they are presented here.

reaching 90—with diamonds,[29] and offshore oil[30] becoming economically viable and a considerable increase in crude bitumen reserves.

Over the next several years, the index hovered around 85, fluctuating modestly as a drop in energy reserves was partly offset by a rise in mineral reserves. In 2003, for example, energy reserves declined 4.6%, while mineral reserves grew 2.9%. In 2006, primarily because of a sharp increase in crude bitumen reserves, the aggregate reserve index jumped 16%—the highest yearly increase—and in 2010, peaked at 113. During the last few years, the index hovered around 108. In sum, the NRRI fluctuated substantially, heavily influenced by the upward shift in energy assets.

Chart 5: Relative share of energy and mineral resource wealth



From 1990 to 1999, the relative shares of energy and mineral resource wealth oscillated around 50%, mainly because of fluctuating resource prices[31] (Chart 5). In 2000, energy resources

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[29]Canada's first diamond mine, the Ekati diamond mine—located about 300 kilometres northeast of Yellowknife, Northwest Territories—came on stream in October 1997. For details, see: http://www.iti.gov.nt.ca/diamonds (accessed February 20, 2016).

[30]In 1979, the Hibernia oil field—located 315 kilometres east-southeast of St. John's, Newfoundland—was discovered, and in November 1997 became the first offshore oil extraction site in Canada. For details, see, http://www.economics.gov.nl.ca/bulletins/oil.asp (accessed March 3, 2016).

[31]Statistics on aggregate price fluctuations are beyond the scope of this paper; prices of individual resources can be obtained from: Bloomberg market.

emerged as the dominant component, accounting for 84% of total wealth. The reserve index is used to shed more light on fluctuations in monetary wealth.

VI. An Indicator of Sustainable Development

Natural capital covers biotic and abiotic components of the ecosystem along with the services they provide, and as a result is frequently cited as a principle of sustainability[32]. The index offers a capacity to produce a measure for a subset of those components. The NRRI is an example of using an existing environmental account, the NRAA, to derive an indicator capable of capturing links between the economy and the environment. The index demonstrates the value of natural capital in a country over time, and provides more insight into the sustainability aspects of our economic behaviour thus monitoring progress to indicate if future generations have the same or better level of wealth compared to past generations.

The index can help monitor sustainable development goal (SDG) 12 titled *Responsible Consumption and Production* which measures and tracks sustainable consumption and production patterns. Notably, the NRRI can help identify which resource is depleting faster than it is being replenished thus giving signals of unsustainable use of natural resources. For instance, the latest data from the NRRI shows that Canada is 18 index point lower than it was in 1990 for minerals, highlighting the gradual depletion of Canada's mineral reserves.

The index should be interpreted as providing a measure based on the currently best available data and assumptions. While it provides a comprehensive account of the selected natural resources, it is currently a partial account. Some functions, such as ecosystems services and land, offer potentially significant additional value but further research is needed to be able to include this in the NRRI. Here the index is based on Canada's natural resource wealth, but the NRRI is a flexible tool. The basket of commodities tracked in this document can be modified to include or

[32] For details, see *Gelb, A., Kaiser, K. & Vinuela, L. (2012). "How Much Does Natural Resource Extraction Really Diminish National Wealth? The Implications of Discovery." CGD Working Paper 290. Washington, D.C.: Center for Global Development.*

remove resources based on geography and/or policy conditions. In principle, any natural asset that can be valued is able to be included in the index.

VII. Limitations

1) The significance of the index is more relevant when the natural resource measured is finite. For example, natural resources in Canada are vast and the index does not adequately reflect the behavior of each resource as reserve life is constantly extended. Therefore it would be interesting to test the index on a dataset with a finite resource to see if resource behavior can be captured adequately in order to be used as an indicator of sustainable development.
2) The interpretation of the index needs to be further clarified – for example what is a reasonable use of this index?
3) The index is limited to countries that have the physical and monetary accounts already in place, therefore this index is geared towards those countries that have already adhered to the current SEEA standard – for example European countries that already have this set up.
4) Tracking natural resources in an aggregate manner may overshadow the behavior of each resource. Possibly suggest applying the index to a mineral or to a single energy source as the index itself bundles the commodities and the behavior of each commodity is lost if presented as one aggregate index.
5) This index could be interpreted by some countries as a way to significantly increase wealth by exploiting identified resources, however the accounts can be used as a sustainable indicator through an environmental lens.
6) While the index focuses on natural resources wealth, it fails to capture the ecosystem aspect of natural capital (e.g. value of the decomposition of waste). Information on ecosystem services are usually produced on an ad-hoc basis. Until this data gap improves, indicators on ecosystem services needs to be used in parallel of the index to assess progress toward sustainable development.

VIII. Discussion

With the inclusion of natural resources in the NBSA, Canada's overall national wealth has increased, but so has its volatility. Two other components of national wealth—land and produced assets—typically rise in volume over time, but because of significant changes in prices and physical stocks of resources, natural resource wealth often fluctuates. Land and produced asset prices are largely determined by domestic market conditions, and their prices seldom drop, whereas natural resource prices are mostly determined by the global market, and so are volatile. More importantly, in a growing economy such as Canada's, physical stocks of developed land and produced assets (such as buildings and bridges) are expected to increase. The same cannot be assumed for natural resources, which can fluctuate substantially as a result of large discoveries and reserve revaluation.

This paper presents a chain-Fisher index, by summing the stocks of 13 resources, and links the index with monetary wealth. For much of the 1990-to-2016 period, physical reserves moved in tandem with price and amplified the volatility in monetary wealth. In 2008, for instance, a 8.3% increase in physical reserves augmented the growth of monetary wealth, which increased 85%. However, in some years, the two indexes moved in opposite directions: in 1998, the index rose 8.7%, but wealth dropped 48% as prices plummeted in the aftermath of the East-Asian financial crisis.

IX. Conclusion

Changes in reserves make natural resource wealth inherently volatile, and fluctuations in resource prices often amplify this volatility. Comprehensive understanding of natural resource assets would be enhanced by a reserve index, similar to the one described in this paper. Furthermore, such an index, in conjunction with human capital and produced capital, can be used as an indicator of sustainable development— defined as, development that meets the needs of the current generation without compromising the needs of future generations. With the availability of suitable data, similar indexes can be estimated at the provincial-territorial level. The index can also be used for designing sustainable development strategies, as well as for inter-provincial comparisons.

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