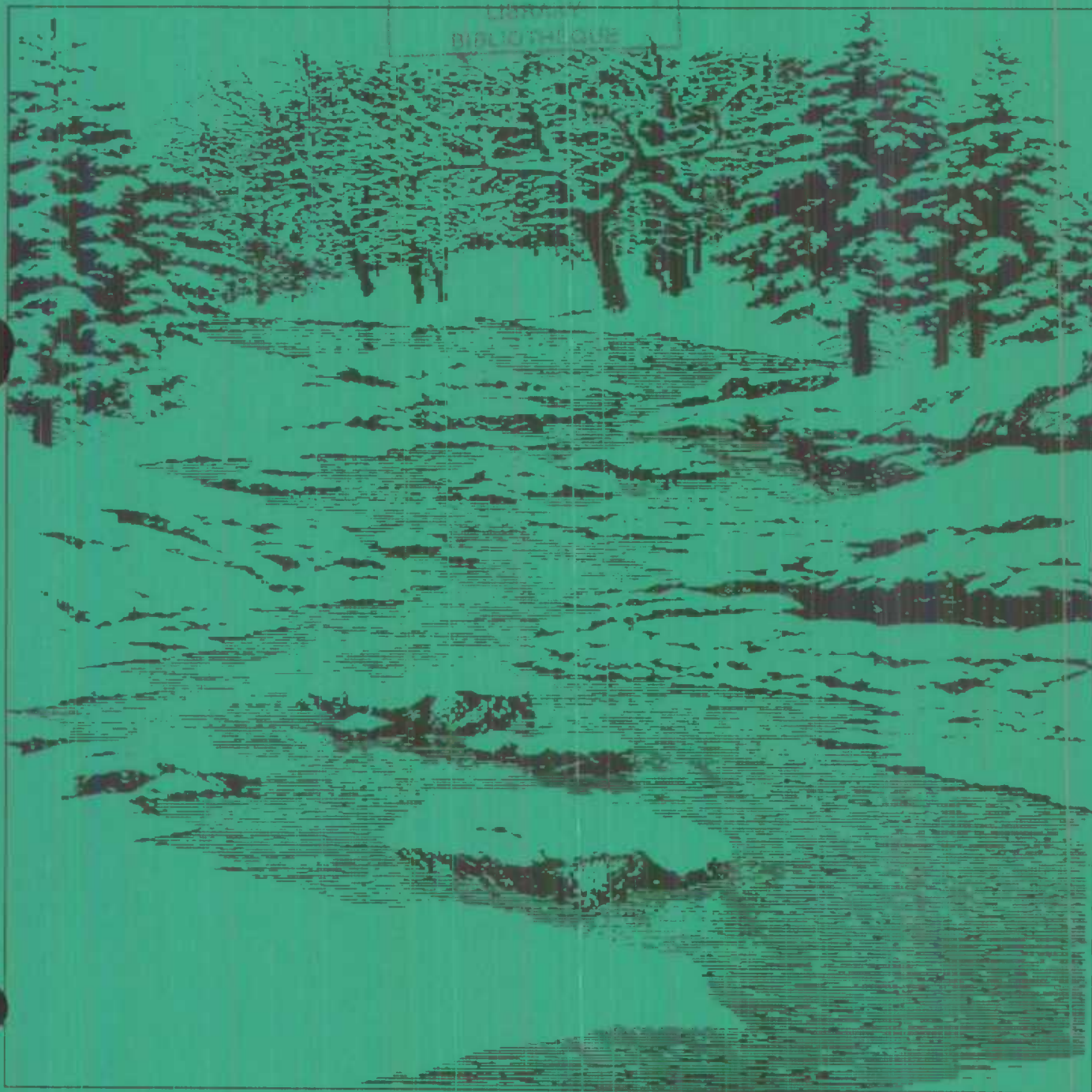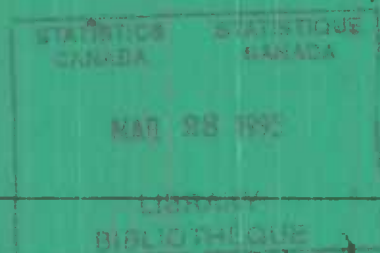# Some Issues in the Development of Natural Resources Satellite Accounts: Valuation of Non-renewable Resources

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**Some Issues in the Development of
Natural Resources Satellite Accounts:
Valuation of Non-Renewable Resources**

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CONTENTS

Introduction and Summary

This note presents some issues related to the development of Natural Resources Satellite Accounts (NRSA) at Statistics Canada. The focus is on valuation issues related to non-renewable resources rather than physical accounts issues. The purpose is mainly to raise the issues to help guiding further research. Please refer to the following summary to guide you into the jungle of ideas presented in this paper.

The first section touches on the definition of reserves that should be considered for valuation purposes. It offers a way to analysis and potentially solve the probabilistic nature of reserves estimates. Above all, this analysis shows the need to study well the probabilistic nature of reserve estimates in order to assess/take account of its impact on valuation.

The second section explores the policy relevance/impact of valuing natural resources. It is argued that efforts should be made to develop one or two prospective valuation approaches, as a wide range of estimates would not lead benefits to society (unless some interpretive definitions could be developed as for unemployment rate). It is also stressed that valuation could have important policy impacts (if not carefully done) because asset values are used as a taxation base in certain municipalities and provinces. It would probably be used more if there was a standard approach that could be used. The valuation approaches already in use for taxation should be reviewed and some attempts should be made to develop an approach that would be appropriate for national accounting but not for taxation purposes.

The rest of the paper deals with valuation measurement issues. Value can mean a lot of different things:

- wealth value: the value of an asset in terms of its contribution to national wealth;

- present value: the economists' formulation of wealth value; it values an asset in terms of its future income production;

- exchange value: the market place value that reflects economic agents' expectations and speculations about the present value;

- *ex post* value: the value that the market should have given to an asset given the income it produced and a realized rate of return;

- replacement value: the replacement value of existing assets should be close to their market value as rational investors are indifferent between buying existing assets or investing in new assets of the same productivity;

- at cost value: the value of natural resources at the net cost (valued added net of depreciation) of providing them;

- book value: the value given by a firm for accounting purposes

- use value: the value of a good in term of its utility/necessity in the production or consumption of other goods (e.g., water is essential to production but has not market value);

- sustainable value: the price that should be attached to an asset and the goods it produces if externalities like user costs - foregone income due to current exploitation of an asset - or pollution were reflected into market prices;

I bumped into these concepts while trying to find an approach or to criticize approaches that have been suggested. The wealth value is what contributes to wealth and it is the reference concept to make judgement on different approaches. The present value concept has been however the economists formulation of this concept and has been the focus in the economic literature.[1]

The third section deals with the present value formula as an approach to value natural resources. It is argued that this formula would lead to different results depending on the assumptions made about the future. This approach could lead useful results if these assumptions could be group together to form distinct interpretative results like for unemployment rate definitions. For example, the present value based on optimal extraction path assumptions could be compared to one based on the extrapolation of past trends. These groupings of assumptions should reflect the interdependence between the unknown variables. The choice of an appropriate discount rate is a key issue and does not seem to have been explored in the literature in terms of applying the present value formula to the SNA.

The fourth section examines the Hotelling's rule as a way to estimate the present value based only on current information. (Hotelling [1931] shows that the value of exhaustible resources in a perfectly competitive economy under certainty depends only on current net income and reserves). Although very appealing, it is argued that this rule is based on theoretical assumptions that are too simplistic to reflect reality and that the empirical evidences either do not support it or did not test it properly. Further research is required to assess the empirical relevance of this approach.

Section 5 discusses the operational definition of the net income stream that should be considered in the present value formula. The total net rent concept (profits minus return on capital plus net government rent) is shown to be the most appropriate concept to value natural resources as a factor of production. Unfortunately, this concept was not properly measure in the reviewed papers and there is no direct measure. The estimation of total net rent is an important challenge.

Section 6 attempts to use another basic economic principle, the intertemporal arbitrage condition, to derive the value of natural resources from current data. This is the *ex post* value approach. The value of an asset at the beginning of a period is determined *ex post* by the net income it generated during that period for a given rate of return. Two different ways of estimating this value are

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1. Present value gives wealth value if all factors of production are perfectly mobile and substitutable (this assumption implies that the discounted future income flow generated by a factor of production is independent of other factors of production such that the present value of factors of production can be added up to total wealth and that each factor of production present value represents its contribution to wealth. Because most natural resources are immobile and potentially non substitutable, present value cannot capture the full contribution of natural resources to a country wealth.

proposed. The first one make assumptions about the definition of the rate of return on capital and economic depreciation of resources. The second way write the intertemporal arbitrage condition in a regression equation where the unknown variables can be estimated rather than defined. The limitations of these approaches are discussed. In the first case, the assumptions are somewhat questionable and, in the second case, data availability might be a problem. Both methods can not value non-exploited reserves as they have not generated income yet. It is worth pursuing for valuating exploitable reserves.

Section 7 discusses briefly the operational definition of economic depreciation of non-renewable resources which is very important for the *ex post* valuation approach. Hartwick's definition is questioned and it is suggested to invite Hartwick at Statistics Canada to help resolve some of these basic issues.

In Section 8, the Land Price Method is discussed. As statisticians, we tend to rely on exchange value because it is easier and relevant to assume that markets "know" the present value. But, transactions on reserves alone rarely happen. Investors however buy mining rights. Landefeld and Hines [1985] have developed what they called the Land Price Method in order to translate these prices into present value. This method should not be used as it can not be justified.

Section 9 deals with the replacement approach. Rent is considered as return on acquisition costs (exploration, development, royalties and others). It is argued that this approach should, in theory, provide good estimates of the present value of natural resources. In practice, however, there might be some important distortions brought about by government interventions. It is worth pursing.

Section 10 argues that total net rent can not capture all the benefits a country might receive from its natural resources. Because they are immobile and not perfectly substitutable, they provide indirect benefits that other factors of production can not.

Section 11 presents an alternative to the factor of production approach: the sectoral approach, where national wealth is broken down by sectors rather than factors of production. This approach would value natural resources at the net cost of providing them to society in usable form.

Finally, in Section 12, other approaches are mentioned without further development.

1. Definition of Reserves/Resources

What do we intend to measure? the reserves, the known deposits that are exploitable using current technology ("assets" approach) or a broader measure of resources, the ultimate resource, that would estimate the potential wealth of the country brought about by its natural resources (wealth approach). It could be argued that it is a matter of variance and bias. The "assets" approach has more probability to generate "its" future income (less variance) but undervalues the wealth of the country (more bias). The wealth approach has less probability to generate "its" future income (more variance) but is, in principle, closer to the true value (less bias).

Is there a logical solution to this or is it an unsolvable problem unless arbitrary choices are made? There might be a parallel between the way future income is discounted and the probabilistic nature of reserve estimates. One argument for discounting is time preference and time preference has uncertainty (probability) attached to it. In other words, we discount future income because the probability of producing/enjoying future income decreases with time. A similar argument could be made for "discounting" resources: the probability that a deposit generate future income decreases with the probability that the deposit exists. This raises the question of an appropriate "discount" rate.

A reasonable "discount" rate could be derived from the probability attached to a deposit. If there is a 80% probability that a reserve exits then a 20% discount would be applied to this resource estimates. The aggregation over deposits with the same probability of existence should lead to a good approximation of resources for valuation purposes (if the reserve estimates are statistically sound -- Landefeld and Hines [1985] mention there is a significant downward bias in U.S. oil and gas reserve estimates).

An important advantage of this approach would be to deal explicitly with the probabilistic nature of resource estimates. It would allow, for the same resource, the aggregation of deposits with different probability attached to them. Moreover, aggregation of present value across natural resources can be justified even if the resource estimates have different probability of existence.

This suggestion might not work in practice. But there are two firm conclusions that can be drawn from the above discussion: (1) it is very important to assess the statistical properties of the resource estimates and (2) to aggregate across natural resources, attention should given to harmonize definitions.

2. Policy Relevance/Impact

There is a wide range of valuation approaches giving a wide range of estimates (as shown by Landefeld and Hines [1985]). So wide that unless one or maybe two can stand out as more appropriate, the valuation of natural resources becomes a pure academic exercise with limited implication for policy or public knowledge. I believe therefore that NRSA project should pay as much attention as possible to the development and justification of one or two prospective approaches.

It should be recognized however that a standard approach might have important impact -- maybe

too important and too controversial. One contact that I have at EMR is presently studying subsidies to the mining sector in USA and Canada in relation to the Free Trade Agreement. He claims that valuation of reserves is a very touchy subject because some taxes are based or could be based on this type of assets. He knows that some municipalities in USA value reserves for property tax purposes. He suspects that some Canadian municipalities have such a practice or would be happy to justify new taxes on a standard or official approach to valuation. Moreover, Saskatchewan already taxes potash and uranium reserves and an outside valuation approach could be used to justify a tax increase or decrease. He also mentioned that Manitoba and B.C. tried to levy a tax based on reserve value but had to withdraw partly because of controversies over the parameters to be used in valuation.

It could also be the case that valuation of natural resources have policy impacts that are not obvious at first glance. For example, Aboriginal people might use official Statistics Canada approach to value natural resources involved in land settlement negotiations.

One alternative to the prospective approach is to produce several estimates based on different definitions. The challenge with this alternative is to develop definitions that have some distinct and clear interpretation power like for unemployment rate definitions (hoping that some international standard arises).

The above discussion leads to the following conclusions. First, further study of the potential policy impact of valuation of natural resources has to be done. Second, the project should study present practices in the valuation of natural resources for taxation purposes. Third, an ideal prospective approach would be consistent with SNA practices but somewhat irrelevant for taxation purposes -- for example, including government rent income in such a way that the approach could not be justified for valuation of private holdings.

3. Present Value Approach

The present value approach is the theoretical basis for valuation of assets. The present value (V_o) formula can be written as:

$$V_o = \sum_{t=o}^{t=T} \frac{p_t q_t}{(1+r_t)^t}$$

where $p_t q_t$ is the future income flow produced by the asset being valued (p_t being the unit net income and q_t the quantity produced) ; T the time the asset would last; this income flow is discounted at the rate r_t (it is usually assumed that discount rate are constant in time).

The present value approach requires therefore assumptions about future market conditions (prices, costs, discount rate, production). This becomes a "projection" exercise with several unknown variables. If we make a parallel with demographic projections, the challenge would be to produce about four different "projections" from a range of "reasonable" assumptions.

The present value approach can not therefore produce a range of estimates based on different *definitions* as suggested in the previous section. One way to alleviate this problem would be to

use consistent sets of assumptions. For example, continuation of past trend for quantities, prices and discount rate (as done by Soladay [1980]) could be compared to optimal extraction criteria like the one develop by Hotelling [1931].

This exercise would have at least the advantage of getting some understanding of the relative importance of the unknown variables in terms of the impact on the estimates. Maybe, the discount rate is as important to present value estimates as birth rate is to demographic projections.

There is however a potentially big difference between present value estimates and demographic projections: demographic projections provide information which has direct implications for policy formulation (e.g., immigration can only play a marginal role in offsetting low birth rates). The information content of present value is certainly not as evident. For example, a higher present value due to a lower discount rate could be interpreted in two ways. On one hand, a lower discount rate can mean that future generation income is relatively more important. This is the time preference interpretation. Thus natural resources value is higher and the country is richer if we care more about future generations. On the other hand, a lower discount rate could mean that a lower rate of return on capital/saving is assumed. Thus natural resources are more valuable and the country is wealthier if we assume a more pessimistic view of the future. This is the opportunity cost interpretation.[2]

One important feature of the present value formula is that the unknown variables are not independent. This means, for example, that if we assume that a low value of r, we have to adjust downward the income flow in the numerator to reflect lower productivity gains (implicit in a lower value of r).

Beside the above mentioned issues, discount rate brings in a whole range of economic issues that have been fostered in economic theory as the question of the difference between the private discount rate and the social discount rate. I have not seen any papers on the appropriate discount rate that should be used within the Wealth Accounts.

Another issue involved with discounting is the estimation of the real discount rate (i.e. net of inflation distortion). Future real productivity gains or future interest rate (whatever defined) minus anticipated inflation would have to be assumed. An alternative to the estimation of real discount rate is to factor in inflation in future income flow, this factor being consistent with current value of r.

4. Hotelling's rule

Based on neo-classical micro-economics of firms behaviours, Hotelling [1931] concluded that free market will produce exhaustible resources in a way that will ensure unit net prices to increase by

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2. These two interpretations are valid because, in theory, discount rate is the intersection of the time preference curve and the opportunity cost curve. Thus, like the supply and demand curve, assuming any future intersection point does not tell which curve "causes" the change, unless the shapes of these curves are known.

the "force" of interest. This rate in the numerator of the present value formula offsets the discount rate in the denominator. The present value of resources would therefore depend only on current estimates of unit net prices and reserves. The Hotelling present value formula can be written as:

$$V_o = (p_o - c_o) R_o$$

where V_o is the present value estimate; R_o is the quantity of units in reserves; p_o is current marginal revenue (the unit market price in free markets); and c_o the marginal cost.

As argued by Hamilton [1989], the Hotelling's rule is appealing because (1) no explicit assumptions have to be made about future market conditions, (2) it is relatively easy to implement and (3) it is a very simple concept to communicate to users. There are two issues related to the implementation of Hotelling's rule to natural resources valuation.

The first issue is whether the theoretical assumptions used to derive the Hotelling's rule are good enough to justify its uses for valuation. In fact, the Hotelling's rule is based on economic assumptions that are quite restrictive and unrealistic like known and constant supply and demand curve.

Levhari and Liviatan [1977] have relaxed some of Hotelling's restrictive assumptions (like complete exhaustion and constant production costs) and concluded that "The principle that marginal profit [net prices] has to increase over time exponentially at a rate equal to the rate of interest (r per cent rule) is shown to be valid only under special conditions." (p. 177). They also conclude that "the rate of growth of marginal profits - apart from being less than r - bears no particular relationship to it." (p. 185) Their argument are quite convincing at the micro level. It is clear that a firm can decide to stop production before the mine is exhausted because the cost of extraction is increasing as the reserves are exploited. In such a case and for constant selling prices, marginal profits are a decreasing function of time not an increasing exponential function. Hartwick and Olewiler [1986; 75] show that high setup costs imply that output and rents are constant over time.

In a Hotelling's world, deposits size and quality are known and the highest quality deposits are exploited first. The fact that mines of distinct and differing quality are exploited at the same time has serious implication for the Hotelling's rule. Firms can arrange extraction path according to this rule only if they operate sequentially deposits of distinct and differing quality (see Hartwick and Olewiler [1986; 73]). If firms can not extract according to this rule, net prices can not go up at the rate of interest.

Bradley [1985] argues that man-made capital is so intensively used for non-renewable resource extraction that factors related to the maximization of return on capital are more important than those related to the maximization of rent (the income related to natural resources). Therefore, extraction patterns are not determined in a way that ensure unit net prices to increase at the rate of interest.

Hotelling's world is a world of certainty but the mining world is a world of uncertainty. There are several uncertain factors in mining: future prices, future extraction costs, future discoveries and development of substitute. Theorists have tried to introduce these real world factors into Hotelling's theory (see Hartwick [1989] for an overview). It is argued that net prices should go up

at the rate of interest even with uncertain. These conclusions are based on the assumption that firms can control extraction paths to ensure that selling prices offset expected losses due to uncertain factors. These conclusions are therefore valid only if firms expectations are met and if they can control output and, thus, selling prices, which was seen to be difficult if not impossible.

The second issue is whether or not the Hotelling's rule can provide good approximation of actual behaviours regardless of theoretical imperfections. (Investors might be using the Hotelling's rule for its simplicity or for lack of alternatives.)

One obvious problem with the Hotelling's rule is that current unit net prices should only reflect the static long-run economic equilibrium. This implies that natural resources prices should be quite stable through time. The historical fact is that raw material prices (in absolute and relative terms) are very unstable because supply and demand change quite rapidly and political factors have a major impact on prices. Is it therefore appropriate to assume that current net prices are determined in such a way as to warrant that future unit net prices will increase at the rate of the discount rate?

It might be the case that firms behaviours tend to the Hotelling economic long-run equilibrium but that rapid changes in the basic factors underlying their behaviours generate important cycles around the secular trend. This would imply that the Hotelling's net price could be approximated by the long-run trend in actual net prices. It would be interesting to analyze the historical net price series to assess if they increase in average at the rate of interest[3] and if a trend approximate Hotelling's long-run equilibrium net prices.

Miller and Upton [1985] have tested the empirical validity of the Hotelling's rule for valuation purpose (what they call the Hotelling Valuation Principle or HVP). This is a very interesting article because the authors go through the implications of Hotelling's theory for practical valuation. For example, Hotelling's theory is based on marginal profits which are not available. They then transform the Hotelling's valuation formula in order to use available data:

$$\frac{V_o}{R_o} = \alpha + \beta(p_o - \bar{c}_o)$$

where α is a constant term representing a complex set of constant terms resulting from using average costs instead of marginal costs and from relaxing some assumptions like constant returns to scale and constant extraction costs; β is a coefficient that should be equal to unity if there was no government interventions (the authors make the argument that important government interventions in USA petroleum industry can not be fully captured in prices and costs movement -- for USA, β should be lower than unity); p_o represents unit market prices; and $\bar{c}_o$ average extraction costs.

Miller and Upton uses this equation to test HVP, the dependent variable being stock market value

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3. The partial literature that I have seen suggest that net prices did not grow exponentially given the relative weakness of raw material prices in the 50's and 60's.

of the Company owning energy reserves. In other words, they test if HVP is a good indicator of how the stock market value energy reserves. They found that "the estimated Hotelling values account for a significant portion of the observed variations in market values and that the Hotelling measures are better indicators of the market values of petroleum properties than two widely cited publicly available alternative appraisals."(p. 1)

These conclusions are the strongest arguments that I have seen for using the Hotelling's rule. However, there are several important problems invalidating their conclusions or adding difficulties to the implementation of Hotelling's rule.

First, Miller and Upton's results imply that valuation of exhaustible resources using HVP might require the estimation of a constant term. The authors argued that this constant term should be closed to zero. I computed that their estimated constant term is significantly different from zero at the 5% level but not at the 1% level. This constant term might be relatively small but there is no information in the article that can be used to test this (α equals 2.24 but it could be thousand, millions or billions of dollars). Should α value be tested with Canadian data?

Second, the coefficient term β might have to be estimated for Canada because the authors results suggest this coefficient to be significantly lower than unity for USA and, above all, Canadian energy policies differs from that in USA. This is a very difficult issue because this coefficient changes with policy changes. The decision to "adjust" or not the Hotelling value depends on the relative weight of the following opposite arguments. On one hand, it could be argued that the Hotelling value is the "true" value for the country -- the regression coefficient only means that the Hotelling value is distorted by government policies. On the hand, a low coefficient must reflect some future income lost due to government interventions and, therefore, the "true value" to private investors is the market value. The "right" argument depends mostly on what happens to this lost income. If it is captured by government and is included in the estimated government net rent, then the "true" value is the market value (the adjusted Hotelling value). If this income accrues to government or the labour force and is not included in estimated government net rent, then the Hotelling value should not be adjusted.

Third, the way Miller and Upton define prices and costs is not consistent with Hotelling's theory. This point is discussed in more details in the "On Net Prices" section.

To conclude, the Hotelling's rule is very appealing for its simplicity, but it can not be applied to renewable resources and more research have to be made or articles have to be found that justify its use for non-renewable resources.

5. On Net Prices

For the above two approaches, net prices is a key concept. The following discussion begins with the concept in the Hotelling world which would then be generalized to the present value approach.

According to Hotelling's theory, unit net prices should be measured as the difference between unit market prices and marginal costs (marginal costs include return on all factors of production except natural resources) which Hartwick [1989] calls the Hotelling rent or scarcity rent to distinguish it from the Ricardian rent.[4]

In the studies that have read however, unit net prices seem to have been measured as the difference between market prices and average extraction costs net of government net subsidies. This is a profit concept where profits include the Ricardian and Hotelling rent and return on capital. It should be noted moreover that this concept has not been measured properly because reported profits do not include interest payments that represent part of rent and return on capital.

Miller and Upton [1985] claim to have justified the use of average costs instead of marginal costs for their investigation.[5] The difference between these two concepts is buried into the regression constant term which is not very important for their research (the slope is) but would be very important for the NRSA project (both the constant term and the slope determine the value). These authors don't mention the return on capital issue but deduct nonpetroleum assets from the "market" value to be tested against the "Hotelling value". To be consistent, this "Hotelling value" should be computed with unit net prices excluding return on capital and the Ricardian rent. But they use unit net prices which are derived from sale prices and operating costs. This inconsistency might have major implications for their conclusions. In essence, they are testing that present value of profits (rent plus return on capital) is a good indicator of the market value of natural resources only. The coefficient β would be much bigger if only the Hotelling rent was used[6] (this coefficient has to be "one, or a bit less" to validate HVP).[7]

It is easy to demonstrate the inconsistencies of this approach by looking at the implications of applying the Hotelling's rule to the Ricardian rent and return to capital along with the Hotelling rent:

$$V_0 = \sum_{t=0}^{t=T} \frac{q_t \left(hr_t + rr_t + rc_t \right)}{(1+r)^t}$$

where hr_t is the Hotelling rent per unit produced; rr_t the unit Ricardian rent; and rc_t the unit return to capital. If we assume that this unit income flow increases at the rate of interest r, then this equation can be written as:

$$V_0 = \sum_{t=0}^{t=T} \frac{q_t hr_t (1+r)^t}{(1+r)^t} + \sum_{t=0}^{t=T} \frac{q_t rr_t (1+r)^t}{(1+r)^t} + \sum_{t=0}^{t=T} \frac{q_t rc_t (1+r)^t}{(1+r)^t}$$

This equation implies that the Ricardian rent per unit produced has to increase at the rate of interest. This can happen only if marginal units are produced first (from low to high Ricardian rent) which is not a rational behaviour. Return on capital per unit produced should also increase at the rate of interest. Given that $rc_t = \dfrac{rK_t}{q_t}$ where r is the rate of return on capital K_t, the capital

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4. The Ricardian rent or differential rent accrues to owners of inframarginal mines. The Hotelling rent accrues to all owners as the difference between the unit market price and the most marginal cost mine. This scarcity rent is required by owners of reserves to offset the lost in asset value due to extraction.

5. It seems that their justification does not allow for the possibility of the Ricardian rent.

6. Bradley [1985] argues that return on capital and Ricardian rent are probably relatively more important than Hotelling rent.

7. It seems like a major flaw in their research, so major that I am wondering if I did not miss something and I am checking on their data sources -- hard to find.

required to produce one unit has to increase by the rate of interest for any given rate of return. It is reasonable to assume that capital per unit increases as more marginal units are produced but this rise should reflect physical rather than financial constraints.

It is obvious that treatment of return on capital and Ricardian rent is a key issue for the Hotelling's approach. On one hand, their is no direct measure of Hotelling rent (profits minus return on capital and Ricardian rent) that is required to apply Hotelling's rule. On the other hand, there is no economic rationale and it is not consistent with current accounting practices to consider return on capital and the Ricardian rent as having a exponential growth offsetting the discount rate. This implies that **profit figures (including both rent and return on capital) should not be used in Hotelling's present value formula.**[8]

Moreover, the treatment of return on capital is a key issue for the present value approach as well. In fact, if one assumes that profits is the right income flow to be considered in valuing natural resources for the present value approach, then the measurement problems are not being completely solved. In fact, these assumptions would imply doubling-counting of man-made capital assets in aggregate wealth accounts (as the present value of future return on capital represent the value of man-made capital assets used in the resource sector which is already accounted for). This could be solved by deducting man-made capital assets value estimates from "total" natural resources value estimates. The only country that includes underground resources in their Wealth Accounts, Japan, is using this approach. This solution lead to at least two considerations.

First, a value of natural resources estimated residually from two estimates based on very different approaches might be questionable (like the old saving rate problem). On one hand, "gross" natural resources value would be derived from present value approaches, which is income based. On the other hand human-made capital in the resource sectors are estimated at their replacement value, which is based on expenditures.

Second, share of the economic rent goes to government. In fact, the Hotelling rent is sometimes called "Royalty" because it represents the lost in value of the mine that the extracting firm as to pay to the owner. This implies that government net rent income from resources should be part of net resource value. In fact, if one excludes government rent, the contribution of natural resources to net domestic wealth would be quite minimal because a good portion of Canadian natural resources private rent goes to foreigners. The first challenge here is to measure the concept of government net rent. Should all subsidies and taxes be considered or only government interventions specific to the resource sector? If the later, is it possible to separate across-industry and industry-specific taxes and subsidies? The second challenge is to estimate the present value of government net rent. Since future royalties depend on extraction patterns, we are facing the problems identified in the "Present Value Approach" section.

The rent concept of net price might seem a logical outcome, but brings in a curious contradiction.

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8. The only two articles that we have found so far that applied Hotelling's rule for valuation purposes (Miller and Upton, and Landefeld and Hines) have use profits as net prices.

If natural resources are gifts of nature, is it appropriate to consider the flow of rent induced by its ownership as a contribution to wealth? Ricardo would probably agree that it is not.

This is a very interesting and important issue. On one hand, a country is wealthier if it has natural resources (rent influences income distribution among countries). Thus the present value of rent income should be considered as assets. On the other hand, the world economy is not as wealthy as it could be because it has to pay a rent to have access to natural resources. (Rent does not ensure optimal resource allocation.) I will come to this issue in "Replacement Value Approach" section.

To conclude, the concept of net private and government rent seems the proper income flow to be considered in the present value formula but is not directly observable. Profits could be used for the private sector in the present value formula but would require to deduct non-resource assets in order to estimate natural resource value alone, which might lead to questionable results because present accounting practices are based on costs rather than income. Moreover, profits can not be used with the Hotelling's rule.

6. The *ex post* Value: a Simple Estimation Approach Based on Rational Behaviours

The above three sections were dealing with the present value approach. It became obvious that the present value approach could produce a wide range of estimates given different assumptions. To alleviate this problem, we look at "The Economics of Exhaustible Resources" in order to reduce assumptions. The Hotelling's rule, the basic principle, was seen as an oversimplification of reality. Further theory extensions have been made but, although more realistic, they do not help to simplify estimation as they require more assumptions (for example, Hartwick [1989] derives the present value of reserves in which profit maximization takes account of technology, capital and labour. The resulting formula requires assumptions about technological changes, capital and labour productivity,etc.). There is however another basic economic principle that is used in this branch of economics that can potentially be applied to valuation. This principle is called the intertemporal arbitrage condition and is formulated as:

$$P_t - D_t = r_t V_t$$

where t is used to identify flows during a given period and t is used with stocks and means the beginning of the period; P_t is profit; D_t depreciation; r_t rate of return; V_t value of asset producing the net income $P_t - D_t$.

This equation means that the value of an asset at the beginning of a period is determined by the net income it generated during that period, for a given rate of return. This formula can provide therefore the *ex post* value of an asset or, in other words, what the value of this asset should have been given the net income it generated. This approach is very interesting because valuation depends only on historical data rather than assumptions about the future.

There are two possible ways to use this approach. The first one involves the following steps:

1. Assuming that the rate of return on capital for extracting equipment is the same as the one for the economy as a whole, compute the net income due to man-made capital using the

(already) estimated value of capital in the extracting industry.

2. Deduct this return on capital and man-made capital depreciation from total profits to obtain total rent.

3. Compute the economic depreciation of reserves by applying El Serafi's formula (see El Sarafi [1989]) -- using the same value as in (1) for r.

4. Compute the net income from resources by deducting economic depreciation of reserves from total rent.

5. Compute the value of natural resources using the intertemporal arbitrage condition with r set as in (1).

This paper does not deal explicitly with the proper way to estimate economic depreciation of non-renewable resources. Thus any other formula that further research might lead to, could be used in (3).

The second way to value natural resources is to estimate the unknown parameters by regression. The following derives the regression equation and then presents some possible issues related to this approach.

It is reasonable to assume that decisions about maximization of return on capital and on rent are taken simultaneously so that for non-renewable resources (this should also be true for renewable resources), this intertemporal arbitrage condition can be rewritten as:

$$TP_t - (DK_t + HR_t) = r_t(VK_t + VR_t)$$

where TP_t is Total Profits (Return on capital plus Ricardian Rent plus Hotelling Rent); DK_t is man-made capital depreciation; HR_t is the Hotelling Rent or economic depreciation of non-renewable resources; VK_t is the value of man-made capital and VR_t the value of reserves.

If we generalize this behaviour to all extracting firms, we can derive the following equation,

$$TP_{t,i} - DK_{t,i} = r_{t,i}VK_{t,i} + r_{t,i}VR_{t,i} + HR_{t,i}$$

where the subscript i stands for extracting firms. The unknown variables in this equation are $r_{t,i}$, $VR_{t,i}$ and $HR_{t,i}$. It is obvious that further assumptions have to be made in order to estimate these unknown variables.

$r_{t,i}$ represents the rate of return on the value of both the reserves and capital that each firms have achieved during period t. It is reasonable to assume that the *ex post* value of reserves hold by a firm would be determined according to the average rate of return achieved in its industry (and ultimately by the rate of return in the economy), so that $r_{t,i} = r_t$ for all i.

For $VR_{t,i}$, it is reasonable to assume that the value of reserves of a given quality is proportional to the quantity of reserves of that same quality (this is economic quality rather than physical quality as it refers to factors determining extraction costs). In order words, firms put a unit price (p) to

each quantity in reserves (R) of the same quality (g). It is also reasonable to assume that all firms would put the same unit price to reserves of the same quality (if firms had a different unit price, then transactions would happen and force unit prices to an equilibrium). This assumption makes a lot of sense since the Ricardian Rent is equal to $rVR = Total\ Rent - Hotelling\ Rent$, and is also determined by the "economic" quality differential in reserves. It is therefore important to stress that some quality distinctions have to be made about reserves for this assumption to lead valuable results. If data are not available, reserves should be restricted to the narrowest definition possible. Thus,

$$VR_{t,i} = \sum_g p_{t,g}\, R_{t,i,g}$$

If we put $\alpha_{t,g} = r_t\, p_{t,g}$, then

$$r_t VR_{t,i} = \sum_g \alpha_{t,g}\, R_{t,i,g}$$

Since the Hotelling Rent accrues to all owners as the difference between unit market prices and marginal costs, we can state that:

$$HR_{t,i} = hr_t q_{t,i}$$

where hr_t represents the Hotelling Rent per unit extracted and q_t the quantities extracted by firm i.

Thus, we can rewrite equation (1) as:

$$TP_{t,i} - DK_{t,i} = r_t VK_{t,i} + \sum_g \alpha_{t,g} R_{t,i,g} + hr_t q_{t,i}$$

In this equation, the unknown variables (r, $\alpha(g)$ and hr) are function of time while the available variables (TP, DK, VK, $R(g)$, and q) are function of time and firms. This implies that for each period, the unknown variables become the coefficient to be estimated by a regression across-firms. The regression coefficients could then be used to compute the value of reserves. One important advantage of this approach is that it would provide an estimate of the Hotelling Rent which than could be used to adjust Net National Income for economic depreciation of non-renewable resources. The stock and the flow estimates would be done therefore in a consistent way.

What are the issues or problems this approach might lead to?

The first issue has to do with the economic meaning of this approach. The regression equation means that extracting firms profits net of capital depreciation are determined by the return on capital through the rate of return and the value of capital, by the Ricardian Rent through the quantity and quality of reserves and by the Hotelling Rent through a Hotelling unit price applied to quantities extracted. This seems like an identity equation but it should be emphasized that this intertemporal arbitrage condition would be used by any rational investor to determine the value of an asset (if an asset does not lead to a rate of return higher or at least equal to the average rate of return, its initial value was too high and its *ex post* value should reflect this. There is however one practical problem with this regression: the Hotelling rent estimation would require that the most marginal mines be included in the sample. If they are not, then some of the estimated Hotelling rent would represent Ricardian rent.

The second set of issues/problems is related to data availability. First, this approach requires some breakdown of reserves by firms in terms of extraction costs or "economic" quality. Second, The value of man-made capital has also to be available at the firm level. Third, this information has to be available at the firm level by type of resources, as one firm might owns gold and coal mines (it might be possible to assume that firms owning both coal and gold mines could be group together for the regression estimation -- by expanding the right hand side of the equation). This lead to the question of degrees of freedom. There has to be at least as many firms as there are coefficients to be estimated. (Another idea: make the coefficients to be estimated independent of time and regress on time. This will increase the number of degrees of freedom and/or avoid data availability problems at the firm level. This would have to be worked out.)

The third issue is whether or not regression estimation techniques can produce statistically sound coefficient estimates given the data. In fact, some care should be given to the choice of the regression estimator because there should be collinearity between the exogenous variables (e.g., q_t is determined partly by VK_t).

Fourth, it might be more appropriate to assume that firms decisions are based on each deposit rather than the sum of them (which is assumed in the above equation). The approach should still be valid if it extended to each deposit because it is as reasonable to assume that the coefficients (r, $p(g)$ and hr) are constant across deposits as it is to assume that they are constant across firms. If data by deposit are available for each dependent and independent variables, the results might even be more reliable given that the number of degrees of freedom would be increased.

But, thinking about the approach in terms of deposits shows that there might be a problem with estimating total profit. There are plenty of deposits that are not exploited. These deposits do not generate operating profits and they do not require capital (thus, $VK = 0$ and $DK = 0$) or Hotelling rent (as $q = 0$). This implies that the value of these deposits is equal to zero, unless profits include capital gains on the value of deposit whether realized or not (in this particular case, the *ex post* value of the deposit at the beginning of the period is equals to r^{-1} times these capital gains). If profits in the regression equation include this type of capital gains, the regression equation can be rewritten as:[9]

$$OP_{t,i} - DK_{t,i} = r_t VK_{t,i} + \sum_g (r_t\, p_{i,g} + hr_t)\, q_{t,i,g}$$

where $OP_{t,i}$ stands for operating profits.

This new regression equation permits the estimation of $(g+1)$ coefficients while there are $(g+2)$

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9. The demonstration is the following. Capital gains results from an increase in the unit price of reserves (at the beginning of a given period) that were not exploited during this period. If we break down this unit price into unit price by quality, then capital gains (KG) are $KG_{t,i} = \sum_g (p_{t+1,i,g} - p_{t,i,g}) \cdot (R_{t,i,g} - q_{t,i,g})$. According to the intertemporal arbitrage condition where profits include capital gains, $p_{t+1,i,g} = (1+r_t)p_{t,i,g}$. Then, $KG_{t,i} = \sum_g (r_t p_{t,i,g} R_{tdot,i,g}) - \sum_b (r_t p_{t,i,g} q_{t,i,g})$. Since $TP = OP + KG$, the first term on the right hand-side of the equation defining KG would cancel the second term in the regression equation. And, the second term defining KG would be combined with the third term in the regression equation as a function of $q_{t,i,g}$.

unknown parameters. Only r can be estimated. This is already an interesting result but can not solve the valuation problem. (I just though that assuming KG as a linear function of mining sector stock market variation or even better as a linear function of market price minus average extraction costs might solve this problem -- but this would have to be worked out.)

Thus, the issue of reserves not currently exploited (having therefore no *ex post* value until they are exploited) but having a positive market price (because they might generate income into the future) can not be dealt only within the intertemporal arbitrage condition. On one hand, the capital gains variable that should be added to the intertemporal arbitrage condition equation to take account of non-exploited reserves is not measurable or estimable (unless further assumptions are made). On the other hand, excluding these capital gains would mean that non-exploited reserves have no value.

It is worth stressing that this approach can only provide estimate of the value of reserves to investors. The value to the government has to be estimated independently.

7. On the Definition of Economic Depreciation of non-renewable resources

There might be a problem with Hartwick's definition of economic depreciation of non-renewable resources. He claims that the Hotelling rent is the proper way to estimate the economic depreciation of non-renewable resources. This proposition implies that economic depreciation per unit produced is the same for all deposits regarless of their quality. One would think that a rich mine would loose more value by quantity extracted than for a "poor" mine. Hartwick [1989] uses the intertemporal arbitrage condition to derive his proposition. I get the opposite result using the same condition (?).

The basic intertemporal arbitrage condition is:

$$P_t + \dot{V}_t = r_t V_t$$

where $\dot{V}_t$ is the absolute change in the value of the asset during period t.[10] Thus, for non-renewable resources that we assume to be valued independently from capital, as Hartwick assumes,

$$TR_t + \dot{VR}_t = r_t VR_t$$

If we divide reserves into two categories: the first one including all reserves that are extracted in time t (RE_t), and the second one includes those are still hold after t (RH_t), then

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10. For convenience, most people put the change in value asset as depreciation. This only shows that capital gains should be part of income flow. It could be shown that this formulation of the intertemporal arbitrage condition leads to the same results obtained in the previous section where capital gains are included and Hartwick's definition of Hotelling rent is used.

$$TR_t + V\dot{R}H_t + V\dot{R}E_t = r_t(VRE_i + VRH_t)$$

Given that $VRE_{i+1} = 0$, $V\dot{R}E_t = -VRE_i$. Given that the value of reserves that are hold should increase by the rate of interest *ex post*, $V\dot{R}H_t = r_t VRH_i$. Thus,

$$TR_t - VRE_i = r_t VRE_i$$

This equation means that the depreciation on the value of exploited reserves is simply the value of these reserves at the beginning of the period. From this, we can derive that

$$VRE_i = \frac{TR_t}{(1+r_t)}$$

This implies that depreciation depends on Total Rent which includes Ricardian Rent. In other words, a rich mine depreciates more by quantity produced than a poor mine.

This equation suggests an interesting and simple way to estimate economic depreciation of non-renewable resources, once Total Rent is estimated.

Obviously, the operational definition of economic depreciation of non-renewable resources is a key issue. Hartwick has strong point of views on this topic. I would suggest to invite Hartwick to Statistic Canada to help sort out this issue and others.

8. Exchange Value: the Land Price Method

As statisticians, we tend to rely on exchange value because it is easier and relevant to assume that markets "know" the present value. But, transactions on reserves alone rarely happen. Investors however buy mining or harvesting rights. Landefeld and Hines [1985] have developed what they called the Land Price Method in order to translate these prices into present value estimates.

Their method assumes that investors value deposits (VR) at the cost of buying mining rights (B) plus the present value of royalties (R) to be paid on extraction (this means that investors do not expect to get any return on land, i.e. not rent. They also assumed that royalties are a fixed proportion (n) of the value of the deposit. Thus, $VR = B + nVR$, and

$$VR = \frac{B}{(1-n)}$$

Obviously, n has to be known. The authors do not mention its value nor how to get it. The following shows that n can not be known from current royalty "rates".

Royalties are usually charged against sales or quantities or, in some cases, profits. In the case of royalties charged against sales, the starting equation of their demonstration has to be:

$$VR = B + \sum_{t=0}^{\infty} \frac{n_t S_t}{(1+r)^t}$$

The summation reflects the fact that royalties are a known fixed proportion of total sales S_t. If we assume that n is constant relative to time, it can be taken out of the sum such that:

$$VR = B + n\, PVS$$

where PVS means present value of sales. It is obvious that, to derive Landefeld's equation from the last equation, one has to assume that the present value of sales is equal to the present value of reserves. This is a rather strong assumption to say the least. It just does not make sens.

In the case of royalties charged against quantities, the assumption does not make more sens: the discounted quantities produced have to equal the present value of reserves.

In the case of royalties charged against profits, the present value of reserves has to equal the present value of return on capital (since there is no return on land by assumption). It is a rather bizarre idea: value an asset by the present value of another one.

This shows that, even if the assumption that n is a fixed proportion of VR is good, n can not be derived from current royalty "rates".

This method produced very low estimates relative to the present value approach and the Hotelling's rule. In fact, Landefeld and Hines give two reasons to explain the low estimates they get: (1) the speculative nature of bidding induces low bids relative to present value and (2) the available data are incomplete. The no return on land assumption, although not mentioned by the authors, must also plays an important role.

To test the relevance of different methods, Landefeld and Hines, computed their implicit rate of return and compared them to the rate for total non-financial corporate sector. They found that the Land Price Method gave the best results (?). This empirical evidence however is irrelevant given that the formula they used can not be justified without an *a priori* knowledge of the proportion of the value of natural resources that goes to pay royalties.

Thus, the Land Price Method as formulated by Landefeld and Hines should not even be considered as a method to test. However, one could value frontier reserves using only the mining right costs as a proxy because this is the only exchange value the market provides on these assets.

9. Replacement Value Approach

I struggled with the rent dilemma mentioned in "On Net Prices" until Rob Smith suggested that rent might also represent the return on past exploration investments (natural resources are not just gift of nature -- they have a value only if discovered). More generally, rent is the return on all acquisition costs (exploration and development costs plus mining rights and maybe royalties).

This lead me to think that acquisition costs could even serve as a proxy for the value of natural

resources in a way consistent with actual valuation of other tangible assets in the Wealth Accounts. The perpetual inventory method is used with tangible assets to obtain replacement value estimates. This means, I believe, that the perpetual method is used to compute the total quantity of tangible assets (the sum of investment goods) which is multiplied by the current market price of the corresponding investment goods to obtain the total replacement value of the tangible assets.

The economic justification of this approach (existing assets are worth as much as their replacement value) is based on the assumption that investors give the same value to assets of same productivity and that existing assets are as productive as new assets. The later assumption is rather strong given technological changes influencing productivity in man-made capital but would not represent a major problem for non-renewable resources if the replacement value approach is applied to the different "quality" of reserves (i.e. the value of high quality oil is given by the exploration and development costs of finding high quality oil). The replacement value of non-renewable resources would be the sum of the replacement value for reserves of the same quality, which would be the unit acquisition costs of newly discovered reserves for a given quality times the total amount of reserves of this quality.

Another way to justify the replacement value approach is that, for risk neutral investors, the value of an existing deposit of a given quality should be equal to the expected costs of discovering a similar deposit, expectation based on recent average acquisition costs; if not, these investors would buy the cheapest one until an equilibrium is reached.

What are the potential issues or problems that might arise with this approach?

First, to reflect the fact that old reserves might have cost less to discover than newer reserves, it could be argued that past acquisition costs value in current dollars should be used for the corresponding reserves discovered in the past. But recent acquisition costs are more in line with the present value of net rent. The Ricardian Rent results from the fact that a reserve benefits from lower costs of production than the more marginal mine which extraction costs determine the floor market prices. Given that exploration and extraction costs should increase as more marginal mines are exploited, current costs represent a better proxy of future rent income flow.

Second, it could be argued that the replacement value might not represent a good proxy of present value of future net rent income. But replacement value is as good for non-renewable resources as it is to other tangible assets. In fact, investors take account of future income stream in choosing (pricing) between the purchase of existing assets and the discovery of new assets.

Third, since world market prices determine domestic prices, international acquisition costs should be used to compute unit replacement values. This argument is only valid if there is no more exploration in Canada. If there is exploration and discovery, then some investors believe that the unit replacement value of reserves in Canada is low enough to justify exploring rather than buying existing deposits.

Four, government exploration subsidies are so high that acquisition costs of newly discovered reserves is small and even negative for the investor. This argument can be done for other tangible assets but not as strongly since there are important social benefits associated with discovering reserves. This is an empirical question that should be looked at.

Five, if rent is assumed to represent only the return on exploration investments (not of ownership), then government net rent should not be part of the natural resources value unless they provide a net subsidy to exploration. There is probably no way around the fact that at least part of the rent represents some rewards to ownership.

Six, the most serious problem however would be to estimate the present value of government net rent since the replacement value would only capture the present value of private net rent.

This approach might not work in practice, but thinking about exploration costs as a distinct feature of natural resources lead to some interesting and important considerations.

First, should exploration costs be included as part of total costs to be deducted from market prices to obtain net prices? In the Hotelling world, there is no exploration costs as reserves are known. Moreover, the marginal cost concept exclude all fixed costs. Finally, exploration costs should not be part of current extraction costs because they represent costs attached to unknown reserves.

Second, replacement value could also be used to estimate the economic depreciation of non-renewable resources. Unit replacement value time the quantity extracted in a given period would provide how much it costs to "maintain the stock of capital intact". This is a very interesting and appealing way to estimate economic depreciation of non-renewable resources.

10. Wealth Value: Can the Present Value Approach Measure the Full Contribution of Natural Resources to Wealth?

It could be argued that the present value approach understates the contribution of natural resources to the wealth of a country, i.e. the wealth value of natural resources.

The present value concept has been however the economists formulation of wealth value and has been the focus in the economic literature. Note that present value gives wealth value if all factors of production are perfectly mobile and substitutable. This assumption implies that the discounted future income flow generated by a factor of production is independent of other factors of production. This, in turn, implies that the present value of factors of production can be added up to total wealth and that each factor of production present value represents its contribution to wealth. There are two reasons to believe that these assumptions are too restrictive for natural resources.

First, natural resources are not mobile like labour and capital. This implies that natural resources don't have the same value to a country as would have man-made capital or labour which are more mobile. Firms have to move capital and labour to natural resources, not the opposite. Even when capital and labour is completely imported and that government net rent is zero, the country receives benefits from the indirect activities (unless all the factors of production in these indirect activities are also imported and their income exported, which not likely). This means that labour and government receive part of the benefits from their country natural resources wealth.

Second, as well demonstrated by Victor [1990], natural resources don't follow the neo-classical assumption of complete substitution between factors of production. This assumption is important because it justifies breaking down wealth into its factors of production: no factor of production

depends on the availability of others (their values are therefore independent). This argument of course is only valid at the global level as a country can substitute its lack of resources by man-made capital and imported resources.

11. At Cost Value: the Sectoral Approach

This section approaches valuation from a sectoral rather than a factor of production perspective.

In theory, national wealth could be defined as the discounted value of the future net domestic income stream. This national wealth could be breakdown in terms of factor of production, which would provide the value of each factor of production: human capital, man-made capital and natural resources. This is an income perspective, i.e. the present value of future income flow accruing to each factor of production.

The national wealth could also be broken down in terms of production activities, since net domestic income equals net domestic production. The economic activities "producing/providing services to" each factor of production could be group together. Thus, the present value of future value added net of depreciation in the resource industries would provide the sectoral contribution of resources to national wealth. The same could be done for man-made capital and human capital (for the latter, all economic activities providing consumer goods and services would be added up).

To value natural resources at the net cost of providing them in the future would be a good approximation of its wealth value, if all the benefits would accrue to domestic factor of production and if these benefits would not be transfered to other sectors if the resources were not there. This is of course a very strong assumption. Is this overstatement of the wealth value of natural resources greater than the understatement arising from the factor of production approach?

It could be argued that this issue is worth pursuing only if the sectoral approach could be implemented. But, is projecting value added less complex than projecting net rent?

12. Some Other Approaches

There are other ways of getting at the value of natural resources that should be given some considerations to. The following just identify them without going into much details.

- *Survey Approach:* The idea here is simply to ask firms to value their own natural resources. The problem with this approach would be consistency between methods used. Surveys could also be used to get some of the necessary inputs to a method while Statistic Canada would compute the value estimate.

- *Book Value:* The great majority of firms have to estimate all their assets for their shareholders or the banks. These data have criticized because firms tend to overvalue their assets for obvious reasons. To alleviate this problem, the Canadian Institute of Charter Accountants is expected to issue a "pronouncement" requiring extracting firms to provide estimates in quantity and value of proved, semi-proved and potential reserves. These estimates would be

subject to audit, which should improve data quality.

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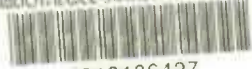
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