Value and Depreciation of Mineral Resources Over the Very Long Run:
An Empirical Contrast of Different Methods

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ABSTRACT

The paper contrasts empirically the results of alternative methods for estimating the value and the depreciation of mineral resources. The historical data of Mexico and Venezuela, covering the period 1920s-1980s, is used to contrast the results of several methods. These are the present value, the net price method, the user cost method and the imputed income method. The paper establishes that the net price and the user cost are not competing methods as such, but alternative adjustments to different scenarios of closed and open economies. The results prove that the biases of the methods, as commonly described in the theoretical literature, only hold under the most restricted scenario of constant rents over time. It is argued that the difference between what is expected to happen and what actually did happen is for the most part due to a missing variable, namely technological change. This is an important caveat to the recommendations made based on these models.

Keywords: Value, depreciation, mineral assets, net price, user costs, imputed income, environmental accounts

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1.Introduction

The paper compares the empirical results of alternative methods of estimating the value and the depreciation of mineral resources over the very long run. The methods considered are the present value, the Hotelling valuation principle, the net price method, the user cost method and the imputed value method. These methods are at the core of the environmental adjustments to the national accounts proposed in the literature. The paper aim at filling the gap between the considerable progresses made towards resolving basic theoretical issues and the lack of agreement on the empirical side about the most appropriate methods for making specific adjustments. Even the most recent attempts of applying environmental accounting do not settle for either the net price or the user cost method.[1] The empirical contrast carried out in this paper use the historical data of to major oil producers, Mexico and Venezuela, from the 1920s to the 1980s.[2] The Mexican experience resembles is one of a closed economy for the period 1938-1970s while Venezuela fits the pure resource exporter model during the whole of 20th century.

After this introduction, the second section survey methods to calculate the value and depreciation of a mineral resource. The Fundamental Equation of Asset Equilibrium will serve as general framework for presenting an array of seemingly competing methods of estimating the depreciation of natural assets, two of which (net price and user cost) have now found its way into the proposed systems of environmental accounting. The other two, present value and imputed income, have been lees often

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[1] See for instance, Newmayer, E. (2001). 'Measuring Genuine Savings: Are Most Resource-extracting Countries Really Unsustainable?'. *The Sustainability of Long-term Growth. Socioeconomic and Ecological Perspectives*. M. Munasinghe, O. Sunkel and C. de Miguel. Cheltenham, UK, Edward Elgar**:** 422-443., pp.422-443; Hansen, A. C. (2001). 'Estimating Non-renewable Resource Capital Consumption'. *The Sustainability of Long-term Growth*. M. Munasinghe, O. Sunkel and C. d. Miguel. Cheltenham, UK**:** 397-421., pp.397-421, or the recommendations made in Nordhaus, W. D. and E. C. Kokkenlenber, Eds. (1999). *Nature's Numbers: Expanding the U.S. National Economic Accounts to Include Environment*. Panel on Integrated Environmental and Economic Accounting, Committee on National Statistics, Commission on Behavioral and Social Sciences and Education, National Research Council. Washington D.C.

[2] Data series assembled by Rubio Varas, M. d. M. (2002). Towards Environmental Historical National Accounts for Oil Producers: Methodological Considerations and Estimates for Venezuela and Mexico over the 20th Century. London, London School of Economics**:** 317.

used in applied studies. An important conclusion derives from the analysis of the different methods: they seem to apply to different scenarios. Hartwick does by implication say the user cost method does not apply to a closed economy case.[3] Sefton and Weale argue that the net price method does not apply to open economies, and from their theoretical propositions it can be inferred that, at least in part, the user cost method applies to the open economy case.[4]

The arduous task of fitting the real world into these theoretical models the main contribution of the paper. The theoretical models implicitly assume that depletion takes place under very strict assumptions (optimal depletion, constant prices, and constant marginal extraction costs, homogeneous reserves and perfect information to mention some). The third section analyses how far from reality these assumptions are from the historical data. The effects of removing the assumptions from the models will be explored in the fourth section. There the methods are applied to the historical data set. The concluding remarks end the paper.

2. Value and depreciation: the theory

Natural resource wealth is usually defined as the present discounted value of all future resource rents.[5] Therefore the value of a natural resource, V_t, is calculated as the sum of the expected net revenue flows discounted at nominal or real interest rates for the life of the asset, which in its compact form can be expressed as:

$$V_t = \sum_{n=0}^{R_t/q_t} \frac{N_{t+n}}{(1+i)^n} \qquad [2.1]$$

Where the expected life of the resource for a given year *t* is given by *n,* - taking values from cero to the limit set by the resource to production ratio, R_t/q_t,- and *i* is the social discount rate.

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[3] J.M.Hartwick, , 'Natural resources, national accounting and economic depreciation'.
[4] J.A.Sefton, and M.R. Weale, 'The net national product and exhaustible resources'.
[5] Lindholt, L. (2000). 'On Natural Resource Rent and the Wealth of a Nation. A Study Based of National Accounts in Norway 1930-1995.' *Statistics Norway. Research Department Discussion Papers* **281**., p.6.

The selling price of an asset, where competition exists, should be equal to this value V_t. The market rate of interest is i. So if the asset (the mine, the oil well) is sold and the proceeds are 'banked', the 'profit' or return after a period elapsed is $iV_t/(1+i)$.[6]

The alternative to selling the asset is to keep the asset for a period. The benefits of owning a capital asset for a period is composed of two items; first, N_t, the per period rent earned by using that asset, and second, the capital gain or loss incurred when the asset is sold at the end of the period, $V_{t+1} - V_t$. In equilibrium, the benefits of selling the asset should equal the benefits of 'holding' the asset. Thus the fundamental assets equilibrium equation states:

$$iV_t/(1+i) = N_t + (V_{t+1} - V_t) \qquad [2.2]$$

Rearranging, the change in value of the asset during the period is

$$V_{t+1} - V_t = \left(\frac{i}{(1+i)}\right)V_t - N_t \qquad [2.3]$$

The change in value of the asset should be equal to the difference between the receipts, N_t, and the true income. The general assumptions regarding mineral assets have a limited time horizon, and that the natural asset continues to be extracted at constant pace until exhausted generating a stream of rents. Under those assumptions the change in value can be identified with the natural asset depreciation, i.e. the decline in the value of the asset due to its depletion over time. This equation serves to frame several conceptually equivalent methods of computing depreciation: the present value method, the net price method, the user cost method and the imputed income method.

2.1 The present value method

The left-hand side of equation [2.3] suggests that depreciation could be calculated based on the difference in the present values from one year to the next. The calculation of the change in the value of the asset using the present value of contiguous years becomes theoretically possible, but in order to become operational

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[6] This section derives from Hartwick, J. M. and A. Hageman (1993). 'Economic depreciation of mineral stocks and the contribution of El Serafy'. *Toward Improved Accounting for the Environment: An UNSTAT-World Bank Symposium*. E. Lutz. Washington, D.C., pp. 215-216.

the present value needs assumptions regarding the behavior of N_t in the future, which involves assumptions regarding extraction rates, prices, costs, etc.

2.2 The net price method

In order to overcome this problem, at least one theoretical proposal has been made regarding the optimal behaviour of the rents (N_t) generated by non-renewable resources. It is known as the Hotelling rent theory.[7] According to this theory, the price of a depletable resource includes two components: the production cost and the resource rent or depletion cost.[8] As a consequence the Hotelling rent is defined as the difference between the price of the resource and the marginal cost of extraction, that is $u=(p-mc)$.[9] The Hotelling rent reflects the unit value of the natural stock. Thus to optimise rents derived from the resource, increases in rent per unit due to increasing scarcity will be set equal to the rate of discount, or in other words the rate of change in rental will exactly match the rate of interest. This can be illustrated as follows:[10]

$$\frac{(u_{t+1}-u_t)}{u_t}=i \qquad [2.5]$$

Since the rent per unit is assumed to rise annually by the rate of interest, expected future rents can be expressed as a function of present rental:

$$u_{t+1}=u_t(1+i); \quad u_{t+2}=u_t(1+i)^2; \ (\ ..... \ ); \quad u_{t+n}=u_t(1+i)^n \qquad [2.6]$$

Total annual rent in year t (N_t) is the product of the quantity extracted (q_t) and unit rent u_t in that year:

$$N_t = q_t u_t \qquad [2.7]$$

Substituting into equation [2.1] the value of the mine in year t can be expressed as:

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[7] Hotelling, H. (1931). 'The Economics of Exhaustible Resources.' *Journal of Political Economy* **39**(2): 137-175..

[8] Ibid. and also Dasgupta, P. and G. Heal (1979). *Economic Theory and Exhaustible Resources*. Cambridge, Cambridge University Press..

[9] Bartelmus, P., E. Lutz, et al. (1993). 'Environmental Accounting : an operational perspective'. *Valuing The Environment: Proceedings of the First Annual International Conference on Environmentally Sustainable Development held at the World Bank, September 30-October 1, 1993.* I. Serageldin and A. Steer. Washington D.C. Appendix 1, p.170.

[10] The algebraic manipulation that follows belongs to Crowards, T. M. (1996). 'Natural Resource Accounting: A Case Study of Zimbabwe.' *Environmental and Resource Economics* **7**: 213-241., p.216-217.

$$V_t = q_t u_t + \frac{q_{t+1} u_t (1+i)}{(1+i)} + \frac{q_{t+2} u_t (1+i)^2}{(1+i)^2} + ... + \frac{q_{t+n} u_t (1+i)^n}{(1+i)^n}$$ [2.8]

which simplifies to

$$V_t = (q_t + q_{t+1} + q_{t+2} + ... + q_{t+n}) u_t$$ [2.9]

Let us define Q as the total stock of resource in year t, i.e. the sum of all possible future quantities extracted. Then the value of the resource in a given year is Qu_t, which is known as the Hotelling Valuation Principle (HVP). The present value of the resource in the following year is then:

$$V_{t+1} = \frac{1}{(1+i)}(Q - q_t)u_{t+1} = (Q - q_t)u_t$$ [2.10]

The depreciation is the loss in value due to the use of the asset during a given period, derived from V_t minus V_{t+1}, so that equation 2.3 simplifies to

$$V_t - V_{t+1} = Qu_t - (Q - q_t)u_t = q_t u_t = N_t$$ [2.11]

Thus according to this simplification the depreciation of an asset can be calculated by estimating the total rent for the year, Nt, where $N_t=(p - mc)q_t$.. Thus, thanks to the Hotelling rent theory, we can in theory estimate the depreciation of the mineral assets without having to calculate the total value of the resource, just by using the rents generated in the current year. This method is known as the net price method.

The net price method was first used by Reppetto to estimate the depletion of Indonesian oil reserves, and has become one of the standard methods in environmental accounting.[11] The net price method is based upon the premise that total profit from resource extraction represents Hotelling rents (with normal profit regarded as necessary cost of extraction). A first problem is that this surplus may be composed of several distinct types of rents in addition to the resource rent. These could include rents due to the differences in the costs of production, monopoly rents due to the exercise of market power in setting price, or ownership rents claimed by the

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[11] Repetto, R. (1989). *Wasting Assets: Natural Resources In the National Income Accounts*. Washington, D.C., The World Resources Institute.. Repetto advocated adding the discovery of new resources to the income in the year of discovery. Most users of this method, calculate the net price adjustment without treating new discoveries as income see for example, Van Tongeren, J., S. Schweinfest, et al. (1993). 'Integrated Environmental and Economic Accounting: A Case Study for Mexico'. *Toward Improved Accounting for the Environment: An UNSTAT-World Bank Symposium*. E. Lutz. Washington, D.C.; U.S. Department of Commerce (1994, April). 'Accounting for mineral resources: issues and BEA's initial estimates.' *Survey of current business*: 50-72..

owners of the resource in the form of royalties, surface taxes, etc. The assumption in the net price method that total profits reflect only Hotelling or scarcity rents implicitly assumes that marginal costs of extraction remain constant. Hartwick and Hageman show that when marginal costs are rising, total profits can be expected to overestimate Hotelling rents by including a proportion of rents derived from holding the assets (Ricardian rent).[12]

There are some other possible distortions on the cost side of the formula that are mostly ignored by the literature. For instance, state-owned enterprises are likely to have higher production costs than firms operating in competitive markets.[13] This is relevant and recognised for Venezuelan PDVSA, Mexican PEMEX, recently privatised Argentinean YPF, etc. Higher costs mean lower value of the rent, and the subsequent underestimation of the resource rent for those countries. The consequence is that part of the resource rents that ought to have been re-invested for sustainable development has already been spent on inefficient production in the current period.[14] In the extreme case an oil sector that is being subsidised may result in negative rents if the gross revenue cannot afford the production costs. This can be easily the case in a country in which oil prices are set artificially low in order to lubricate the rest of the economy, such as in Mexico.[15]

All in all, it would be hard to imagine a set of assumptions more at odds with the actual characteristics of resource use in most countries than the assumptions underlying the Hotelling rent, and thus the net price method:[16]

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[12] Hartwick, J. M. and A. Hageman (1993). 'Economic depreciation of mineral stocks and the contribution of El Serafy'. *Toward Improved Accounting for the Environment: An UNSTAT-World Bank Symposium*. E. Lutz. Washington, D.C.

[13] The view of Amuzegar, J. (1999). *Managing the Oil Wealth: OPEC's Windfalls and Pitfalls*. London., p.10 that 'state ownership of oil ...made misallocation, inefficient use, waste and misappropriating much easier than if the reserves had been in private hands' seems to be widely accepted.

[14] Santoprieto, G. D. (1998). 'Alternative Methods for estimating resource rent and depletion costs: the case of Argentina's YPF.' *Resources Policy* **24**(1): 39-48.p. 43

[15] Evidence of negative rents for Mexican oil production can be found in Rubio Varas, M. d. M. (2002). Towards Environmental Historical National Accounts for Oil Producers: Methodological Considerations and Estimates for Venezuela and Mexico over the 20th Century. London, London School of Economics**:** 317., ch.4

[16] Vincent, J. R. (2000). 'Green accounting: from theory to practice.' *Environment and Development Economics* **5**: 13-24., p.21. The last assumption added from Nordhaus, W. D. and E. C. Kokkenlenber, Eds. (1999). *Nature's Numbers: Expanding the U.S. National Economic Accounts to Include Environment*. Panel on Integrated Environmental and Economic Accounting, Committee on National Statistics, Commission on Behavioral and Social Sciences and Education, National Research Council. Washington D.C., chapter 3. The comment that follows belongs to the former source.

- optimal management (in presence of state enterprise and/or monopoly/oligopoly)
- endogenous prices (most countries are price takers on international prices)
- endogenous costs (technological advance has driven extraction costs steadily downward)
- absence of production constraints (in general producers do face production constraints)

In situations where these assumptions are violated, which are most empirical situations, the simplification of the net price method becomes misleading. This theoretical analysis will be endorsed in the fourth section, when the method will be implemented with real data.

Finally, the net price method may also overstate the true depletion cost since it does not consider that the surplus for a depletable resource also includes a part that can be consumed. In principle, the net price method allocates the full rent for reinvestment in order to guarantee the consumption level of future generations. It has been argued that, in presence of technological change, re-investment of the entire surplus value would mean that future generations would inherit a capital sum far greater than necessary for them to receive an after depletion revenue equal to that received by the present generation.[17]

2.3 The User Cost method

Along these lines, El Serafy has argued that only a part of the rents generated by the resource are to be reinvested for guaranteeing future consumption.[18] El Serafy argued that the surplus for a depletable resource represents two values: (1) a true income component which can be consumed; and (2) a separate depletion costs. The depletion costs or 'user cost', should be set aside year after year and invested to create a perpetual stream of income that would provide the same level of true income, both during the life of the resource and after the resource has been exhausted.[19] The user

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[17] Mikesell, 1994, *Resources Policy,* n.20 as quoted by Santoprieto, G. D. (1998). 'Alternative Methods for estimating resource rent and depletion costs: the case of Argentina's YPF.' *Resources Policy* **24**(1): 39-48..

[18] El Serafy, S. (1989). 'The Proper Calculation Of Income From Depletable Natural Resources'. *Environmental Accounting For Sustainable Development: a UNEP- World Bank Symposium*. Y. J. Ahmad, S. E. Serafy and E. Lutz. Washington D.C..

[19] Ibid. p.13.

cost method has been widely used as alternative to the net price and the present value methods.[20]

As the previous two methods (present value and net price), the user cost method can also be thought in terms of the fundamental equation of assets equilibrium [2.2].[21] Here the scenario is one in which the mine could theoretically either be sold and the revenue invested in financial assets, thereby earning interest *X* each year to infinity, or alternatively rentals, *N* could be earned yearly from exploitation of the asset for a finite period of *n* years until reserves are fully depleted, which is given by the reserves to production ratio R_t/q_t. The present value of the finite series, N_t, should equal the present value of the perpetual income, *X*. The present value of the finite series is:[22]

$$\sum_{n=0}^{R_t/q_t} \frac{N}{(1+i)^n} = \frac{N\left[1-\frac{1}{(1+i)^{n+1}}\right]}{1-\frac{1}{1+i}} \qquad [2.12]$$

The present value of the infinite series *X* is:

$$\sum_{n=0}^{\infty} \frac{X}{(1+i)^n} = \frac{X}{1-\frac{1}{1+i}} \qquad [2.13]$$

Setting equations [2.12] and [2.13] equal and multiplying by the denominator gives:

$$X = N\left[1-\frac{1}{(1+i)^{n+1}}\right] \qquad [2.14]$$

Rearranging the equation, the amount representing the 'user cost' is:

$$N - X = N/(1+i)^{n+1} \qquad [2.15]$$

[20] See for instance the pilot environmental accounts of Papua New Guinea in Bartelmus, P., E. Lutz, et al. (1993). 'Environmental Accounting : an operational perspective'. *Valuing The Environment: Proceedings of the First Annual International Conference on Environmentally Sustainable Development held at the World Bank, September 30-October 1, 1993*. I. Serageldin and A. Steer. Washington D.C.

[21] El Serafy argued that depletion of natural resources couldn't be conceptually regarded as depreciation and he suggested that his user cost calculation has to be discounted from the traditional GDP measure. See El Serafy, S., 'The Environment as Capital', in Lutz (ed.) *Toward Improved Accounting for the Environment*, an UNSTAT-World Bank Symposium, Washington, 1993, p. 20-21.

[22] From the Annex 2 of Bryant, C. and P. Cook (1992 Nov). 'Environmental issues and the national accounts.' *Economic trends*(469)..

where *X* is the true income that can be consumed, *N* is the total annual receipts (net of extraction cost), *i* the rate of discount and *n* the further number of years for which current extraction rates could be sustained.

The user costs (or depletion costs) measured by this method is just a mere percentage of the receipts. This percentage depends upon two values, the discount rate *i*, and the expected life of the resource, *n*. In general the greater the life expectancy of the reserve and the higher the rate of discount used, the lower the proportion that the user cost suggests should be reinvested. If the reserves were to be exhausted in one-year time almost the whole of the receipts obtained should not be consumed but reinvested for guaranteeing a sustainable income. If the resource was to last for a long enough period the cash obtained could be almost entirely consumed, reinvesting a minimum amount that goes to zero when the life expectancy surpasses the century.

Observe that in order to calculate the user costs, 'El Serafy needed several assumptions that are likely to bias the estimates.'[23] Regarding N_t, the current level of receipts is held constant during the lifetime of the resource. The rate of extraction is also held constant until the final exhaustion of the resource, thus the life expectancy of the reserve in the present year, *n*, is not allowed to change over time. It also assumes a constant discount rate. Finally, El Serafy is implicitly assuming an open economy, since it needs someone to sell the resource to. Hartwick does by implication say the user cost method does not apply to a closed economy case.[24]

2.4 The imputed income method

Sefton and Weale elaborated what we are going to call the imputed income method. As opposed to the methods discussed above, their departing point is not the Hicksian concept of income. Instead, they place the work of Weitzman in a more general framework and define welfare income as 'the discounted value of the future product

[23] Hartwick, J. M. and A. Hageman (1993). 'Economic depreciation of mineral stocks and the contribution of El Serafy'. *Toward Improved Accounting for the Environment: An UNSTAT-World Bank Symposium*. E. Lutz. Washington, D.C.

[24] J.M.Hartwick, , 'Natural resources, national accounting and economic depreciation', *Journal of Public Economics* (1990) 43.

of the interest rate and consumption along a chosen future consumption path'.[25] Within this general framework their paper derives the necessary adjustment for an open economy which exported natural resources. Their main claim is that the net price method is based on a closed-economy model and therefore it is inappropriate for resource exporting countries.[26] Their suggestion is that an imputed income for the stock of the resource targeted for export should be included in the measures of income.[27]

They construct the adjustment term as the adjustment corresponding to the extraction of exhaustible resources ($-N_t$) plus an income imputed to the stock of the resource due for exports (i.e. the gains from trade), which after some algebraic work comes to $V_t(i/(1+i)$.[28] In this framework, V_t is calculated as the present value of the expected gains from the stock of the resource targeted for exports assuming Hotteling's rule holds. Under these assumptions, V_t can be 'constructed from an estimate of the total remaining stock of the resource and the estimate of the present ratio of the domestic to foreign final consumption of this resource' times the price net of extraction costs.[29] In our notation it translates as $V_t=u_tQ_E$. Observe that, in practical terms the adjustment proposed by Sefton and Weale responds to the formulation described for all the other methods. Depreciation in this case is ($-N_t +(V_t(i/(1+i))$ with the difference that the value of the resource is a function only of the resources made available for exports rather than the total stock.

2.5 Theoretical summary

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[25] J.A. Sefton and M.R. Weale, 'The net national product and exhaustible resources: The effects of foreign trade', *Journal of Public Economics* 61 (1996) p.45. They generalised the model presented in Weitzman, M. L. (1976). 'On the Welfare Significance of National Product in Dynamic Economy.' *Quarterly Journal of Economics* **90**(1): 156-162..

[26] The models explicitly mentioned by Sefton and Weale are Dasgupta, P. and G. Heal (1979). *Economic Theory and Exhaustible Resources*. Cambridge, Cambridge University Press. and Hartwick, J. M. (1990). 'Natural resources, national accounting and economic depreciation.' *Journal of Public Economics*(43): 291-304..

[27] In fact their model suggest two adjustments: an imputed income for the stock of resource targeted for export and a rate of interest effect. Yet, the second adjustment is considered 'harder to estimate and it seems reasonable to assume is negligible as real interest rates can be expected to remain almost constant in the long run', J.A. Sefton and M.R. Weale, 'The net national product and exhaustible resources: The effects of foreign trade', *Journal of Public Economics* 61 (1996), p.46.

[28] See the Appendix in Rubio, M. d. M. (2004). 'The capital gains from trade are not enough: evidence from the environmental accounts of Venezuela and Mexico.' *Journal of Environmental Economics and Management* **48**(3): 1175-1191.

[29] Ibid, p.46.

The four theoretical methods presented for the calculation of the depreciation of mineral resources, give an implicit value to the resource too. The formulations of each method are described in Table I.

[**Table I: Summary of theoretical methods**]

The algebra in all cases is not short of assumptions, as it has been seen above, which help to the simplification of the formulae. For instance, net price in its simplest form has been severely criticized for overestimating both the value and the depreciation of non-renewable resources.[30] The criticisms come from theoretical speculation regarding the mismatch between the assumptions made by the net price method, as seen above, and alternative, more realistic, assumptions regarding the future paths of prices, costs and depletion rates. It is worth recalling here that the net price has also been criticized for being based on the assumption that none of the resource is exported abroad. The user cost algebra relies in the assumption that the rents are identical in consecutive years. Sefton and Weale rely on the assumption that the same share of the resource stock will be targeted for exports in the years to come.

That is precisely why the strategies taken by Mexico and Venezuela and the data used in this paper can help to shed light on this debate. We can now test the actual path taken by the present values and its variation through time, hence directly addressing the issue of depreciation of the resources. It will then be possible to assess whether the net price overestimates the depreciation, by how much, and under what circumstances. It will also be possible to establish the effects of removing the assumptions made by El Serafy for the user cost method, and those of Sefton and Weale for the imputed value method.

3. The historical evidence

Observe that the data requirements of the most used methods are theoretically simple: the aggregate resource rent of the current year, and the quantity produced over the resource reserves available in order to calculate the life expectancy of the resource. How much we have, how much we have used and how long will it last are key questions at the time of valuing any asset. Reserves, depletion, and the production-to-

[30] Davis, G. A. and D. J. Moore (2000). 'Valuing mineral stocks and depletion in green national income accounts.' *Environment and Development Economics* **5**: 109-127., p.111; also see Seroa and Ferraz in the same issue of the journal on the 'tendency' to exaggerate depreciation.

reserves ratio are particularly relevant to the valuation of natural resources. Though only the quantity produced is needed for the calculation of the rent, the total amount held at a specific point in time is required for the calculation of the resource depreciation that will be elaborated in the issuing section. This section presents comparative historical data on the amount of oil used and available for Mexico and Venezuela.

Figure 1 shows production and proven reserves of hydrocarbons in Mexico and Venezuela for the period 1901-1989. Proven reserves are mineral deposits located on or below the earth's surface, which are economically exploitable, given the current technology and relative prices.[31] The term 'reserves' is commonly used for 'proven reserves'. All in all, the reserves available in both countries increased throughout the century -most dramatically in Mexico, whose reserves sharply rose during the early 1970s. Mexico only experienced a significant period of declining reserves from the 1980s onwards. However, this was mostly due to technical adjustments of the extremely optimistic figures produced during the 1970s rather than the result of rapid depletion.[32] In contrast, Venezuela went through a period of declining reserves between the second half of the 1960s and the early 1970s, which coincided with the years of maximum oil output. A plausible explanation is that companies reacted to the impending nationalization process by reducing their productive and exploration activities. 'This determined that the oil industry in Venezuela was in a stagnant situation at the time of the nationalization. The indices of reserves, production, level of employment and reduction of investment in all activities confirm this situation'.[33] Technological change and the increase of the relative price of petroleum made previously un-exploitable resources increasingly available.

[FIGURE 1: PRODUCTION AND RESERVES IN MEXICO AND VENEZUELA]

The fact that reserves available to each generation increased over time sharply contrasts with the implicit assumption behind most writings in green accounting, which assume the increasing scarcity of resources. This may constitute a problem for

[31] United Nations (1993). *System of National Accounts 1993*. New York., paragph.13.59.

[32](1997). Seismic shifts? (Survey 4 of 8). *The Economist*.. In fact, according to Sordo, A. M. and C. R. López (1988). *Exploración, Reservas y Producción de Petróleo en México, 1970-1985*. México D.F., Colegio de México., p.102-103.

[33] PDVSA, (Petróleos de Venezuela S.A.), (1986). *Los primeros diez años de la industria petrolera nacional 1976-1985*. Caracas., p.9.

the current research, if this underlying assumption underpins the models and methods so strongly that they cannot deal with scenarios such as the historical one depicted here with increasing resources over time. This question is explored in section four.

Let us recall it here the different path of production followed by both countries. In brief, one can identify three periods in the history of Mexican oil production. The first extends from the first commercial production of crude oil in 1901 to the nationalisation-expropriation of the industry in 1938.[34] Within this period, Mexico became the second largest producer of petroleum after the United States, and the largest oil exporter. Mexican production first peaked in 1921. However, Mexico did not regain the 1921 level of production until 1974. The second phase runs from expropriation-nationalisation of oil production in 1938 to the mid-1970s. In this period, Mexico was producing mainly for its own internal consumption with a negligible amount of exports, and had become a net importer of petroleum by the late 1960s. Finally, the new era of Mexican energy development was launched by major oil discoveries in the south of the country in 1974, and the country's production and exports experienced an important thrust.

There is a complete series of oil produced in Venezuela since the first shipment in 1917. Venezuela surpassed Mexico's production in 1928, and extraction accelerated thereafter except for a short slowdown in the early 1940s due to the Second World War. Venezuela replaced Mexico as the world's second largest oil producer and kept the position until 1961, when it dropped to the third place thanks to the surge in the Middle East.[35] Venezuela accounted for a maximum of 15 percent of world oil production over the whole period.[36] The late 1960s represented the zenith of Venezuela's production. By then, Venezuela produced ten times the amount of oil Mexico was producing. As consequence of the foreseeable nationalisation, Venezuela's production started to decline from 1970. For its part, Mexico oil production revived in the mid 1970s and achieved its maximum output level in 1982, shortly after surpassing Venezuela's production for the first time in over fifty years.

It is worth mentioning that the difference is more one of pace of extraction rather than one of radically different endowments, since the total endowment is relatively similar

[34] Bermudez, A. J. (1963). *The Mexican National Petroleum Industry: A case study in Nationalisation*. Stanford. p.1.

[35] United Nations. Department of Economic and Social Affairs (1962). *Petroleum Exploration: Capital Requirements and Methods of Financing*. New York., p.3.

[36] Oil and Gas Journal (monthly). 'World overview.' *Oil and Gas Journal*,(December)..

as Table II shows. The contrast between in the rate of extraction is expected to leave its mark in the value of the resources.

[**Table II: Accumulated oil production 1901-1985. Mexico and Venezuela]**

Another set of methods is not concerned with how much we have, but with how much longer the resource is expected to last. The reserves-to-production ratio, namely the life expectancy of the resource, named *n* herein, is calculated by dividing the proven reserves by the amount produced in a given year. Figure 2 contrasts the life expectancy of oil reserves in Mexico and Venezuela for the period 1920-1989.

[**Figure 2: Life expectancy of oil reserves in Mexico and Venezuela 1920-1989**]

Despite having held smaller reserves for most of the period, the slower pace of exploitation allowed Mexican reserves a longer life expectancy than those of Venezuela. Nevertheless, the short life expectancy of Mexican reserves over the 1920s is notorious. It is worth remembering that the peak of production of the first Mexican oil era was in 1921. From then onwards, the lack of discoveries drove *n* downwards in a path hardly broken until the huge discoveries of 1974.[37] These discoveries pushed the life expectancy of Mexican reserves to a level never achieved before: 60 years.

Until the end of 1922, the development of the Venezuelan petroleum industry was restricted. Despite the big number of oil concessions, no great deposits had been found. On December 14th 1922, the blowout of well Los Barrosos No2 showed the world Venezuela's great oil potential and started a rush into Venezuelan oil.[38] After this explosive start with massive discoveries in the early days of Venezuela's oil history - leading the value of *n* to 55 years in 1924- *n* descended to its historical minimum, seven years, in 1929. The slowdown of the production due to the war drove *n* to a peak in 1942. From then onwards, the profile of the life expectancy of Venezuela's oil reserves is quite similar to that of Mexico, with a continuous descent until the early 1970s. The cutback in production after the nationalization in 1976 accounts for the rise of *n* more than any exceptional new discoveries in Venezuela during this last period.

The crucial relevance of *n* to the overall results is revealed in section four. Therefore it is worth briefly reflecting here on the nature of this variable. To what extent can the life expectancy of the resource be understood as a choice variable? To be sure, the addition

[37] For Mexican exploration policies, see Sordo, A. M. and C. R. López (1988). *Exploración, Reservas y Producción de Petróleo en México, 1970-1985*. México D.F., Colegio de México.
[38] Martínez, A. R. (1989). *Venezuelan Oil Development and Chronology*. London., p.39-41.

of new discoveries to the known stock is a highly uncertain activity that relies a great deal on good fortune.[39] Yet it can be argued that the intensity of exploration activities and of the extraction rate depend upon management decisions. In fact, Pemex, the Mexican national petroleum company, adopted a 20-year reserve to production ratio *(n=20)* as official policy during most of the 1950s and 1960s.[40] It is interesting to notice how this policy relates to the result that makes the depreciation equal to zero in Sefton and Weale model. If the ratio production to reserves matches the rate of interest, no adjustment to conventional income is needed within this model.[41] This rule is just the inverse of *n*. If we believe that a 5 per cent is a reasonable long run interest rate, the corresponding life expectancy of the resource is precisely 20 years. If the premises of Sefton and Weale model hold it is reasonable to expect Mexican environmental adjusted income and conventional income should not differ by much. It is not clear whether the Mexican government took this sort of arguments into account when choosing a 20 years time horizon.

Management can influence the value of *n* by either intensifying exploration activities– thus increasing the probability of new discoveries- or by cutting/accelerating the rate of extraction. Since the value of *n* directly derives from these decisions affecting the magnitude of reserves and production, it is clear that there is some discretion over its value.

Yet, for the calculation of the aggregate resource rant marginal cost of extraction would be needed. These are not readily available and empirical studies have used average cost of extraction as an approximation.[42] In fact, the most common way to

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[39] United Nations. Department of Economic and Social Affairs (1962). *Petroleum Exploration: Capital Requirements and Methods of Financing*. New York., p.1.

[40] See PEMEX, (Petróleos Mexicanos) (1953-1960). *Informe del Director General, 1953-1960*. México D.F. and Sordo, A. M. and C. R. López (1988). *Exploración, Reservas y Producción de Petróleo en México, 1970-1985*. México D.F., Colegio de México..

[41] For the algebraic demonstration of this see the appendix in Rubio, M. d. M. (2004). 'The capital gains from trade are not enough: evidence from the environmental accounts of Venezuela and Mexico.' *Journal of Environmental Economics and Management* **48**(3): 1175-1191.

[42] The most notable exceptions to the widespread use of average costs are: Hartwick, J. M. (1990). 'Natural resources, national accounting and economic depreciation.' *Journal of Public Economics*(43): 291-304.. He obtains marginal extraction costs from a series by Adelman. For their part, Vincent, J. R. (1997). 'Resource depletion and economic sustainability in Malaysia.' *Environment and Development Economics*(2): 19-37. and Vincent, J. R., T. Panayotou, et al. (1997). 'Resource depletion and sustainability in small open economies.' *Journal of Environmental Economics and Management*(33): 274-286., convert observed average costs to the marginal extraction cost after forecasting mineral prices and applying a discount rate. Weitzman, M. L. (1999). 'Pricing the limits to growth from minerals depletion.' *Quarterly Journal of Economics* **114**(2): 691-706., p.704 estimates marginal costs to be about 40 percent higher than unit (average) costs for crude oil and natural gas.

calculate N_t has been to obtain the surplus revenue accruing to the owners of the resource after accounting for the contribution of labor and capital inputs.[43] This implies constant marginal costs. In the theoretical exercises, the marginal costs are expected to increase as the resource is depleted. The theoretical implication is then that the total rents calculated using average costs might overestimate the true value of Hotelling rent and therefore exaggerate asset depreciation. In historical terms, however, costs of extraction decreased steadily over the twentieth century thanks to technological advances. This may balance out the theoretical speculation. Figure 3 shows the resource rents (calculated as the surplus revenue accruing to the owners of the resource after accounting for the contribution of labor and capital inputs) for Mexico and Venezuela.

[Figure 3: Resource Rent for Mexico and Venezuela USA $]

Venezuela, given its massive production generated far more rents than Mexico during the century. It is noticeable the mismatch between the historical evolution of the resource rents and the assumptions in the literature. It is clear the rents, historically, did not behave as assumed under the Hotelling principles. The models based on Hotelling's principle, assume prices increase over time while the rate of extraction and the stocks remain constant. It is remarkable that production has never been constant, even at times of little or no discoveries, while prices were almost flat from the 1940s to the 1970s. The absence of technological change in the theoretical models would in part explain the difference between the historical and the theoretical evolution the rents. This divergence between the theoretical assumptions and the actual behavior of the variables is likely to have an impact on the results offered by the methods.

The physical account of hydrocarbon resources in Mexico and Venezuela reveals the increasing availability of economically exploitable deposits over time. Both countries have enjoyed similar endowments with some advantage for Mexico, which is mostly due to the huge discoveries of the early 1970s. This fact, in conjunction with the slower pace of exploitation in Mexico, gives Mexican reserves a longer life expectancy than Venezuelan ones for most of the century. The effects and implications of these facts for the valuation of the resource and its depreciation value will be further developed in the following section.

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[43] Santoprieto, G. D. (1998). 'Alternative Methods for estimating resource rent and depletion costs: the case of Argentina's YPF.' *Resources Policy* **24**(1): 39-48. p.39.

4. Value and depreciation: the empirical contrast

4.1 Empirical contrasts of the values

The four theoretical methods presented for the calculation of the depreciation of mineral resources, give an implicit value to the resource too. It was also seen above that such value implicitly relates to the present value. It is often argued that the implementation of the present value method depends too much on the expected rate of change of oil prices and of the cost of developing the reserves.[44] To be sure, those authors that have attempted to apply this method had no other option but to impose strict assumptions regarding the expected behavior of prices, costs and quantities produced, which are underpinned by implicit assumptions regarding technological stagnation. Assumptions of constant rates of extraction and constant (or semi-constant) rents are commonplace.[45]

However, the availability of historical data enables the calculation of the present value by using actual prices and costs series. This is the equivalent of having perfect foresight from every point in time. It is interesting to contrast the results of both alternatives (keeping the rent constant versus using the actual data assuming perfect foresight) in order to evaluate the potential divergence between the ex-ante and the ex-post results. If they differ by a great deal, those reluctant to apply this method would have one more argument in their favor: that the assumptions bias the results considerably. If, on the contrary, actual data and assumed values result in similar present values, then the method will be endorsed. Speculating about the validity of the present value results under different assumptions has further relevance to the net price, the user costs and the imputed income approaches, since all are based on the present value results, as it was shown in section 2 above.

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[44] Some authors explicitly refuse to apply this approach given the difficulty of having to speculate about future values for prices, quantities, costs of extraction, etc. Examples are Crowards, T. M. (1996). 'Natural Resource Accounting: A Case Study of Zimbabwe.' *Environmental and Resource Economics* **7**: 213-241., p.214 and Santoprieto, G. D. (1998). 'Alternative Methods for estimating resource rent and depletion costs: the case of Argentina's YPF.' *Resources Policy* **24**(1): 39-48., p.41.

[45] Vaze, P. (1996, April). 'Environmental Accounts- Valuing the Depletion of Oil and Gas Reserves.' *Economic Trends*(510): 36-44., p.41 and Common, M. and K. Sanyal (1997). 'Measuring depreciation of Australia´s non-renewable resources: a cautionary tale.' *Ecological Economics*(26): 23-30., p.26.

This section elaborates on the results of implementing equation [2.1] under a variety of assumptions. This first exercise provides us with the present value of the resources, which we can then compare with the Hotelling Valuation Principle (which is the value associated to the net price method), and the values associated with the other two methods. Once the value is known, its change over time can be calculated. Hence the depreciation value can be estimated and contrasted under all four methods

Having all the historical variables in hand, one can calculate the present value implementing equation 2.1 assuming perfect foresight. Take the example of 1920, the first year for which the rent, N_t, has been calculated for Venezuela. In that year, the amount of oil known in the reserves was enough to sustain the production level of 1921 for another 21 years ($n = 21$). Therefore, V_{1920} is the sum of the discounted resource rents obtained for every year up to 1941. Algebraically:

PV1: $$V_{1920} = N_{1920} + \frac{N_{1921}}{(1+i)} + \frac{N_{1922}}{(1+i)^2} + ... + \frac{N_{1941}}{(1+i)^{21}} \qquad [4.1]$$

Under this perfect foresight scenario the rent, the quantity extracted and the time horizon change from year to year according to the historical data set. [46] In equation [4.1], *PV1* adds up the discounted values of the total aggregated rents obtained historically.

However, the most common approach in the literature when implementing the present value method has been to assume that the resource rent remains constant and that extraction occurs at a constant rate until the resource is exhausted.[47] Such an approach

[46] Given that this approach tries to emulate a perfect foresight scenario, it is relatively weak to constrain the time horizon of the reserves to those known in any given year. In a perfect foresight scenario, both Mexicans and Venezuelans would have known their reserves would last longer than the historical data set suggest in any specific year. One could place the aggregate oil available to both economies during the century at the start of their production period and start the depletion from then on. As shown in Table 2, Mexican aggregate production until 1985, plus the reserves in that year, amounted to a total of 83,561million barrels, which can be thought to be available for disposal during the period 1901-1985. Venezuela totals about 68,747 million barrels for the period 1917-1985. That would imply discounting over 2000 years in order to calculate the present values at the beginning of the century!

Alternatively, one could grant a 20-year time horizon throughout the period. This is not the equivalent to an infinite time horizon, but it is long enough to avoid worrying about immediate exhaustion. Calculated this way, the present values for both Mexican and Venezuelan oil reserves continuously rise over time leaving no room to calculate a depreciation value.

[47] Vaze, P. (1996, April). 'Environmental Accounts- Valuing the Depletion of Oil and Gas Reserves.' *Economic Trends*(510): 36-44., p.41 says 'for operationalise this analysis it is assumed that the reserves are depleted a constant rate and that unit rents either stay constant or rise at 3 percent real'. That is, production is set constant. Common, M. and K. Sanyal (1997). 'Measuring depreciation of Australia´s non-renewable resources: a cautionary tale.' *Ecological Economics*(26): 23-30., p.26

presupposes constant prices for oil and constant costs of extraction. To calculate V_{1920}, it entails adding up the discounted value of the rent of 1920 for the 21 years the resource was expected to last. The equation to be used would then be:

$$\textbf{\textit{PV2:}}\ V_{1920} = N_{1920} + \frac{N_{1920}}{(1+i)} + \frac{N_{1920}}{(1+i)^2} + ... + \frac{N_{1920}}{(1+i)^{21}} \qquad [4.2]$$

In equation [4.2], *PV2* calculates the present value of the production of 1920 should the rent and the quantity extracted remain as in the year in question until the expected exhaustion of the resource. That is a different concept from *PV1,* which calculates the present value of the aggregate rents generated in 'future' years, with different rents and quantities from those produced in the year in question.

A further implementation of equation [2.1] is still possible. It calculates the present value of the quantity extracted in year *t*. This is the present value of the expected rents the amount currently extracted would produce in the years to come, allowing the rent per unit (prices and costs) to vary. The justification for this permutation stems from the fact that PV1 implementation is rather incoherent. It uses *n* as the lifetime of the resource every year and yet allows the production to change as it happens in future years. Increasing amounts produced in years to come would be impossible to sustain with the current reserves, only because new reserves are added in years to come, that the increasing production can occur. However, this third permutation allows for the constraint of the life expectancy and also for the continuation of the production as in the current year but accepts that prices and cost vary in the future. So, for our example of Venezuela in 1920, the present value under this variant would be:

$$\textbf{\textit{PV3:}}\ V_{1920} = u_{1920} \cdot q_{1920} + \frac{u_{1921} \cdot q_{1920}}{(1+i)} + \frac{u_{1922} \cdot q_{1920}}{(1+i)^2} + ... + \frac{u_{1941} \cdot q_{1920}}{(1+i)^{21}} \qquad [4.3]$$

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also set the rate of extraction equally for all the years considered. Other implementations of present value methodology applied to resource rents under these very same assumptions are the ones by World Bank (1997). *Expanding the Measure of Wealth. Indicators of Environmentally Sustainable Development*. Washington, D.C., p.32; Lindholt, L. (2000). 'On Natural Resource Rent and the Wealth of a Nation. A Study Based of National Accounts in Norway 1930-1995.' *Statistics Norway. Research Department Discussion Papers* **281**., p.6; And the US Bureau of Economic Analysis net present value estimates according to Nordhaus, W. D. and E. C. Kokkenlenber, Eds. (1999). *Nature's Numbers: Expanding the U.S. National Economic Accounts to Include Environment*. Panel on Integrated Environmental and Economic Accounting, Committee on National Statistics, Commission on Behavioral and Social Sciences and Education, National Research Council. Washington D.C., chapter 3.

where u_t represents the rent per unit (price minus average costs) and *q* the quantity extracted. This is a much more logical way of calculating the present value of year *t* than *PV1* and *PV2.* By multiplying the current production by the present value of the *rent per unit* (rather than by calculating the present value of the *aggregated rents* as in *PV1*), it captures the wealth (i.e. the present value) of the current year's production, should it be sustained until the exhaustion of the reserves currently known. This approach allows changes in prices, costs and discoveries as they occur by allowing the rent per unit to change over time unlike in *PV2.* Table III summarizes the underlying assumptions behind each of the three implementations.

[TABLE III-: UNDERLYING ASSUMPTIONS FOR THE PRESENT VALUE METHOD]

The choice of the social discount rate is more difficult to ground historically. The US Tariff Commission in 1932 used 6 percent.[48] An identical figure was used in 1970 for the calculation of the present value of future production, in order to compensate Pauley&Co for the cessation of the exploration contract this company had with Pemex.[49] El Serafy suggests 5 percent or thereabouts as an approximation to what classical economists used to call a natural rate of time preference.[50] The best possibility is to perform a sensitivity test in order to make explicit the bias introduced by this variable in the calculations. For this purpose, three alternative social discounts have been considered 3, 6 and 15 per cent.

The consequences of the different implementations for the overall performance of the present value at the time of calculating the resource wealth and its depreciation over time are better understood by looking at the results the different implementations produced for our two case studies. Figures 4 and 5 below compare the results of the different values obtained. One might expect movements in wealth to correspond to the periods of increasing reserves (adding wealth) and fast depletion of reserves (decreases in wealth). Per contra, the relation is <u>not</u> to the actual level of the reserves

[48] U.S. Tariff Commission (1932). Production cost of petroleum products and of refined petroleum products. Washington, D.C., p.59.

[49] Echevarría, A., E. Loreto, et al. (1970, 27 February). *Dictamen sobre el valor que representa para Petróleos Mexicanos el compromiso contraido en el contrato Puley-Noreste celebrado originalmente con E.W. Pauley*. México D.F., Pemex., p.3.

[50] El Serafy, S. (1989). 'The Proper Calculation Of Income From Depletable Natural Resources'. *Environmental Accounting For Sustainable Development: a UNEP- World Bank Symposium*. Y. J. Ahmad, S. E. Serafy and E. Lutz. Washington D.C., p.16.

– which increases virtually throughout the period- but to how long the reserves were expected to last.[51]

The different present value permutations depict quite different stories regarding the evolution of the resource wealth of Mexico and Venezuela. The most common implementation, *PV2*, generates the lowest value for the resources compared with *PV1* and *PV3*. This is the case because current rents projected into the future, as in *PV2*, fall short in a world where rents increased both through growing production and improved technology (which lowered the costs of extraction, thus increasing the rent). *PV1* includes both increasing production and technological change (new uses for the resource, reduced costs, etc), and provides the upper limit so long as the pace of extraction keeps increasing over time. Otherwise, if production is reduced in the future, *PV3* takes the lead. *PV3* only includes technological change (since production is kept as in the current year) and may be taken as a middle of the road option. In a scenario where rents per unit and/or production decreased over time, the bias would work in the opposite way. *PV2* will overstate the value of the resource compared to the other two implementations. The social discount rate is not a very important variable. The life expectancy of the resource, *n*, turns out to be a much more important one at the time of shaping the path of the resource value.

There is a further implication of the different implementations. If one wished to increase resource wealth, the strategy would vary. Assuming *PV2* as the value of the resource, the best way of increasing V_t is by raising N_t. The most obvious way to do so would be to increase current year production, q_t. This might reduce *n*, but the expected effect will be still an overall increase of V_t, because:

$$\Delta \sum_{n=0}^{R_t/q_t} \frac{N_t}{(1+i)^n} \geq \frac{N_t}{(1+i)^n} \qquad [4.4]$$

If *PV2* is used, reducing the life expectancy of the resource is the strategy for increasing the value. Using the same argument, a cut in production thus increasing the value of *n*, would not lead to an increase in value. This is because, if the country is a

[51] Reserves levels only declined for the late 1950s and the 1960s.

price taker, the reduction in the rent for every year in the sum can never be compensated by the addition of an extra year of life.[52]

In contrast, if *PV1* or *PV3* are believed to better represent the value of the mineral wealth, expanding the time horizon for the resource becomes an option. An increase in n can be achieved by: (1) increasing reserves or (2) reducing production enough to gain an extra year of life for the resource. It can be argued that the former depends on random factors, but the latter is just a straightforward management decision. In a setting with increasing rents over time it is quite likely that a reduction in q_t sufficient to ensure a further year of production would lead to higher V_t if:

$$\Delta N_t \leq \frac{N_{t+(n+1)}}{(1+i)^{(n+1)}} \qquad [4.5]$$

Given the magnitude of the rents by the end of the period under consideration (1980s), it is not heroic to assume that a cut in production and the consequent rent reduction in year t would be more than offset by the addition of an extra term with big rents at the end of the equation. Therefore, the use of different formulae is not a simple disagreement about the best way of implementing the algebra. It has strategic implications for the management of the resources.

How do these present values compare with the Hotelling Valuation Principle and with the values implicitly assumed by the user cost and the imputed value methods? The net cost implicit assumption is that the value of the resource is that given by the Hotelling Valuation Principle. That is, the per unit rent of the current year times the total stock of reserves, uQ. The actual magnitude of the present value for a given year is also relevant to the calculations put forward by El Serafy. His user cost method proposes to match the present value of the finite income from the resources to the present value of a perpetual income generated by investing part of the rents generated in a given year.[53] His working assumptions lead him to use our *PV2* measure as the

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[52] The price taker assumption is needed as otherwise a cut in production could lead to an increase in prices keeping the rent at the same level or even increasing it. If prices are not affected by the production cut, the aggregated rent will be reduced. The unit rent can also be expected to get smaller in the presence of scale economies.

[53] For El Serafy, setting part of the proceeds aside for reinvestment is only a metaphor. 'The owner may dispose of his receipts any way he chooses. But he should be made aware of the fact that his true income is only a fraction of his total receipts'. El Serafy, S. (1989). 'The Proper Calculation Of Income From Depletable Natural Resources'. *Environmental Accounting For Sustainable Development: a UNEP- World Bank Symposium*. Y. J. Ahmad, S. E. Serafy and E. Lutz. Washington D.C., p.16.

value of the finite income in his calculation, as it is proven in below. Finally, remember that, in practical terms, the adjustment proposed by Sefton and Weale responds to the formulation described for all the other methods ($-N_t + (V_t(i/(1+i))$ with the difference that the value of the resource is a function only of the resources made available for exports rather than the total stock, thus uQ_E..

Figures 4 and 5 demonstrate that the value of the resource assumed in the theoretical models (the middle panel showing HVP, Sefton and Weale and the constant rents assumptions used by El Serafy) differ substantially from the perfect foresight and historical paths (shown in the upper and lower panels). This comparison gives an idea of the deviation between the optimal depletion path assuming no technological change and the historical path that we can assume is technologically determined.

As a general observation, the HPV and the value given by Sefton and Weale (SW in the Figure) are very similar for Venezuela, but very different in the case of Mexico. The reason is clear, while Venezuela exported almost all its production Mexico did not. So in the former case $uQ_E \approx uQ$

[Figures 4 and 5: contrast of values using PV1, PV2, PV3, HVP AND SW]

Concentrate on the middle panel. Here, we observe that the lower is the social discount applied the best is the fit between the Hotelling Valuation principle and PV2. Thus $HVP \approx PV2$ at low social discount rates. Yet the HVP is always above PV2. That is the same result as the one obtained by the literature saying that the net price (which values the resource via the HVP) exaggerates the value of the resource when compared with the user costs (which implicit value is given by PV2).

However, if we move from the middle panel to the alternative calculations of the present value, in the upper and lower panels, the results are quite different. Since PV2 is always below the level of HVP, one can go by comparing the HVP assigned value to the PV1 and PV3 values. In general, looking at the upper and lower panels in both figures, the values assumed in the theoretical models (HVP, PV2, and uQ_E) overstate the value of the resource in the first half of the century and severely underestimate it from the 1950s onwards for both countries. Again, this is the case because current rents projected into the future, fall short in a world where rents increased both through growing production and improved technology (which lowered the costs of extraction, thus increasing the rent and allowed further production). Sefton and Weale rely on the optimal behaviour of rents over time. The sensitivity of the adjustment to the rate of return is a consequence of the fact that the expected gains from trade in this model arise from the application of Hotelling's rule. Dropping this assumption and taking the historical data on exports (rather than keeping the proportion of exports to production fixed) and the historical rents also produce very different results as it can be seen in the upper and lower panels.

Consequently, it is safe to say that the HVP overvalues the resource if, and only if, the value assigned to the resource is that resulting from *PV2*. Otherwise, if the value of the resource is obtained with the historical net returns, the HVP can both under and overestimate the resource value. The conclusions obtained in the theoretical literature about the bias of the different methods are strongly linked to the assumptions they made. Therefore, the biases of the methods, as commonly believed in the literature, only hold under the most restricted scenario of constant rents over time.

4.2 Empirical contrast of the depreciation

Depreciation is the change in value of assets (mineral assets in this case) as a consequence of their use over time. Since the value of the assets has now been estimated, the variation in value can be calculated as the difference among the present values of consecutive years, simply $V_{t+1} - V_t$. In general, negative values are expected from such a calculation. This expectation derives from the underlying assumptions regarding future behaviour of rents and constrain to the life expectancy of the resource, which is normally fixed at its value at time *t*. From simple observation of the series presented above, one can anticipate that a continuous depreciation is an unlikely outcome since the value of the assets shows an increasing trend over time.

Tables IV and V report the differences between consecutive year's present values for Venezuela. That is the direct estimation of the right hand side of the fundamental equation of asset equilibrium presented above (equation [2.3]). Since the net price method is an attempt to approximate the change in value, the last column of each table provides the relevant net price for comparison.

[Tables IV and V: depreciation according the present value method]

As expected, negative changes in value (i.e. depreciation) are not the rule but the exception for the two countries regardless of the implementation used for calculating the present value. In addition, the higher the social discount used, the less frequent depreciation becomes. More crucially, the net price is not a good approximation to the change in value. Worse, contrary to a widespread view in the literature the bias is not systematically upwards. It has become widely accepted that the net price overestimates depletion. Most of the demonstrations (if not all) are theoretical, and therefore subject to the assumptions regarding the alternative scenarios.[54] In our results, the net price both overestimates and underestimates changes in value. The net price seems to have a tendency to underestimate during the first half of the century and to overestimate during the second half.

The periods over which Venezuelan oil resources lost value depend on the formula used. While the variation that assumes perfect foresight (*PV1*) signals the 1920s and the 1940s as the decades with most depreciation, the variation that keeps variables constant (*PV2*) points to the late 1950s and the whole of the 1960s as the years in which more value was lost.

The results for Mexico present some similarities but also important differences when analyzing the depreciation values obtained using the present value methodology. The main similarity, again, is that assuming perfect foresight (*PV1)* generates less years with depreciation than the traditional operational approach (*PV2*) suggests. The sensitivity to the rate of discount also remains. However, here the net price tends almost systematically to underestimate the depreciation obtained from the change in value.

Note that no depreciation is observed at the time of the massive discoveries of the early 1970s. This result is consistent with the fact that the resource base grew tremendously during those years, expanding the time horizon and thus the present value of the resource by virtue of the extra terms added at the tail of the formula. As a consequence, the value of the resource appreciates over time.

This last fact is directly connected with the issue of why the net price is not a good proxy for the change in value of the resources. As used in applied studies, the net price method estimates gross, not net changes in value. 'By making $V_{t+1}-V_t= -(p_t - AC_t)=Nt$ the applied studies have ignored the capital gain (loss) associated with holding the resource (which is conveyed by the first term of equation [2.2], that is

[54] See for example Davis, G. A. and D. J. Moore (2000). 'Valuing mineral stocks and depletion in green national income accounts.' *Environment and Development Economics* **5**: 109-127.. Although the article recognises that under several assumptions the direction of the bias is unknown for the value of the reserves –thus for the depreciation too.

Vt(i/(1+i)). It appeared that the only problem with the net-price method was that it used average costs instead of marginal costs. Unfortunately, this advice was misguided. This is not to say it was incorrect: it was indeed correct, but only under the strong assumptions underlying it. Since the assumptions are violated, the capital gains term in the definition of the change in value becomes important.'[55]

The results demonstrate that the value given to the resource in any given year depend greatly on the assumptions regarding the behaviour of the rent over time. The most common assumption, that of keeping rents constant over time, tends seriously to underestimate the historical present values of the resources in both Mexico and Venezuela. In the absence of better tools for predicting future trends of prices, rates of extraction and costs, and the pace of new discoveries the calculation of depreciation is a hazardous undertaking. In addition, the expectation of obtaining a depreciation value to charge yearly for the use of the resource finds no satisfactory answer in the presence of capital gains.

With regard to methodology, one of the most important findings of the section is the confirmation that the net price is a poor approximation to the change in value of the resource. That should not be new to most experts in the field. What is new is that the results presented here demonstrate that the net price does not systematically overestimate the depreciation values, even under the most restrictive assumptions. The net price both underestimates and overestimates the change in the value of oil resources in Mexico and Venezuela, because it is indeed a measure of gross change in value.

The results also prove that the life expectancy of the resource has a role to play in the value of the resource, which is at least as relevant as the discount rate chosen. This is mostly ignored by the literature as a result of the assumptions regarding the value of *n* over time. This variable depends on both the rate of extraction and the variation of the stock of reserves. Typically, both extraction and stock are held constant which make *n* decrease one year at a time as exhaustion of the resource takes place. In the exercises carried out here, both the rate of extraction and the stock of resources vary constantly and as a consequence, the time horizon of consecutive years can be very different. Therefore, it should be kept in mind that an important part of the change in value over time observed is due to the variations in the time horizon from period to period.

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[55] Vincent, J. R. (Ibid.). 'Green accounting: from theory to practice.': 13-24. p.21. Parenthesis added.

Does the user cost method approximate the change in value better than the net price method? Hartwick and Hageman have already pointed out that, in the case of changing yearly receipts, El Serafy's measure could be a poor approximation to the amounts that can be consumed (reinvested) from the yearly receipts. However, their result was based on the elaboration of a hypothetical case.[56]

The forthcoming paragraphs present the results under the constant rents assumption. Then rents (and thus prices and costs) are allowed to change using the results of *PV1* and *PV3* from the previous section for the calculation of the user costs. This simple exercise demonstrates the user cost reproduces exactly the net change in value (right hand side of equation [2.2]) regardless of the assumptions made about the value of the resource, but that once the assumption of constant rents over time is removed, the amount that can be consumed keep no relation to the rent produced in the current period.

The algebra of the user cost method demonstrates that, if receipts are kept constant, the amount that should be set aside and invested to create a perpetual stream of income is a proportion of the current year receipts. Under this assumption, the proportion is equal to $1/(1+i)^{n+1}$. It is possible to calculate the proportion of net receipts that correspond to the user cost using the historical data of Mexico and Venezuela. The two pieces of information needed are the life expectancy of the oil reserves in the two countries at the current rate of extraction (*n)* and the social discount rate *(i).* We shall see that, given any rate of discount, the variations in the value resulting from the equation are solely due to variations in *n*.

Figures 6 and 7 plot the proportion of receipts that should be accounted as user costs for both countries using the historical data on life expectancy of the resource and considering two values of *i;* 6 and 3 percent. The value of *n* has also been plotted to facilitate the understanding of its influence on the calculation.

[Figures 6 and 7: User costs vs life expectancy of the resource]

Figures 6 and 7 reveal the direct effect of the fluctuations of *n* and of the different values of *i* on the final value. When the time horizon shortens, a higher proportion of the rent is

[56] Hartwick, J. M. and A. Hageman (1993). 'Economic depreciation of mineral stocks and the contribution of El Serafy'. *Toward Improved Accounting for the Environment: An UNSTAT-World Bank Symposium*. E. Lutz. Washington, D.C. p.217.

due to be reinvested. Since Venezuela's oil reserves enjoyed a shorter life expectancy than Mexico's, the user costs suggest Venezuela should have set aside a larger proportion of the rents received for guaranteeing the future flow of income than Mexico. From the early 1970s, Venezuela's oil production slowed down; the lower the amount of oil depleted, the longer the life of the current reserves. The effect of this on the user cost recommendation is that a decreasing proportion has to be reinvested all the way to the end of the period.

It is clear from Figures 6 and 7 that the choice of *i* is also critical for the results. A mere three percentage points of difference in the social discount (from 3 to 6 percent) produces about 20-percentage points difference in the result. Therefore, time preference matters. The lower the discount rate the bigger the proportion of the rents that should be set aside. Yet life expectancy matters also. In presence of a short-lived resource, both social discount rates imply relatively similar high reinvestment policies. This is observable in the late 1920s and second half of the 1960s. However, when the life expectancy of the reserves increases, a smaller part of the rent needs to be reinvested and a bigger percentage of the rent can be consumed. The lower the preference for the future and the longer the life expectancy of the resources, the smaller the amount that should be reinvested. During the 1970s and particularly the early 1980s, Venezuela exemplifies the point. The life expectancy of Venezuelan oil fields grew consistently during those years. Starting from the same rents, the lower preference for the future of 6 percent generates a reinvestment path that decreases at a faster pace than the reinvestment recommendation at 3 percent.

Theoretically, new discoveries do not have to be accounted as income in this approach. Yet, if discoveries occur, and the same pace of extraction is kept, the time horizon automatically increases and so does the proportion of the rent that can be consumed in the current period –since the proportion that needs to be reinvested shrinks. Equally, if the owner decides to keep the reserves-to-extraction ratio unchanged by raising his annual extraction when new discoveries are added, income will also rise through the increase of the rents obtained. Therefore, in practice, discoveries have a direct effect on 'income'.[57]

[57] Reckoning that the market share of the producer is small, thus neither discoveries nor increasing production will alter prices.

So far, the user costs seem to provide a satisfactory answer to our quest for the value that should not be accounted as income (i.e., the value that should be considered depreciation of natural capital and subtracted from traditional measures of income). The problem is that, when the constant rents assumption is removed, the algebra of the sum of geometric series is no longer valid. Therefore, the hypothetical amount that should be reinvested for continuing to yield the same level of income in perpetuity does not correspond to a proportion of the rent. To demonstrate this point, it is necessary to recall the algebra supporting the user cost method, yet in a more simplified fashion than in section two above.

User cost is derived from setting equal the present value of the finite series produced by the resource, *N*, to the value of a perpetual income *X*:

$$\sum_{n=0}^{R_f/q_t} \frac{N_t}{(1+i)^n} = \sum_{n=0}^{\infty} \frac{X}{(1+i)^n} \qquad [4.6]$$

In the previous section, the left hand side of equation [4.6], that is the value of the resource V_t, has been calculated as *PV1*, *PV2* and *PV3* depending on the assumptions regarding the evolution of N_t,. The right hand side is the sum of a perpetual geometric series whose simplified result can be found in any maths book. Therefore the equations can be rewritten as:

$$V_t = \frac{X}{1-\frac{1}{1+i}} \qquad [4.7]$$

for whatever implementation of the present value, V_t. The value of *X* is therefore:

$$X = V_t \cdot \left(1-\frac{1}{1+i}\right) \qquad [4.8]$$

The user cost is meant to be the difference between this true income and the rents obtained every year. Thus user cost is *X-N*, which replacing *X* by the expression in [4.8] and simplifying becomes:

$$UC = V_t \frac{i}{1+i} - N_t \qquad [4.9]$$

which is also the expression for $V_{t+1}-V_t$ derived in equation [2.3].[58] The user cost is therefore equivalent to the net change in value. Now, if *PV2* replaces *Vt* in the equations above, *N-X* becomes the proportion of *N* that Figures 6 and 7 show above,

[58] Hartwick, J. M. and A. Hageman (1993). 'Economic depreciation of mineral stocks and the contribution of El Serafy'. *Toward Improved Accounting for the Environment: An UNSTAT-World Bank Symposium*. E. Lutz. Washington, D.C. p.215.

that is $1/(1+i)^{n+1}$. But if we remove the basic underlying constant rents assumption and we plug *PV1* or *PV3* into the equations above, the results are quite different. Tables VI and VII report the results of applying equation [4.9] to the different values generated for *Vt*.

[TABLES VI and VII: User Cost under different implementations]

Contrasting Tables VI and VII with Tables IV and V in the previous section, it turns out that 'change of the value' calculated here $(V_t(i/(1+i)-N_t)$ does not replicate the 'change in value' calculated there $(V_{t+1}-V_t)$.[59] If the approximation is only rough, it is because our historical scenario does not fit some of the theoretical abstractions supporting the equality. Nevertheless, the contrast of the results for each country remains, since it reveals that outside the El Serafy assumptions, the value of Venezuelan oil resources depreciated to a greater extent and more often than Mexican ones.

According to the numbers in Tables VI and VII, current generations could have consumed far more than the rent they were currently obtaining from the resource. The results show that once the constant rents assumption is removed, the true income, *X*, that represents the amount that can be consumed without jeopardising future generation's ability to consume according to El Serafy, is greater than the rent for a number of years. This is shown by the positive figures in the table. This is a result quite on line with the history of oil producer countries. They could, for instance, borrow against the resources they hold.[60]

Still, the figures generated do not represent a value that can be charged as depreciation for the use of the natural resource in the national income accounts. Although El Serafy himself is not in favour of depreciation methods, he would take away his user cost from the GDP itself, 'for it does constitute neither an economic rent nor a value added to the economy. Thus, it is wrong to describe as current production that which is not, applauding as good economic performance what comes from the liquidation of subsoil assets rather than from labour, capital formation,

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[59] Vincent, J. R. (2000). 'Green accounting: from theory to practice.' *Environment and Development Economics* **5**: 13-24., p. 21, defines in this manner the two sides of the equation.

[60] Both Mexico and Venezuela used oil as collateral for borrowing in international markets during the late 1970s and the early 1980s. In words of P. Lucke, 'oil sales were used to catalyse external borrowing and bring forward high levels of future income', see Luke, P. (1988). 'Debt and Oil-led Development: The Economy Under Lopez Portillo'. *The Mexican Economy*. G. Philip. London., p.70

technological progress and efficient organisation'.[61] But, removing one of El Serafy's assumptions produces an outcome that increases rather than decreases the GDP of resource producers.

Finally we turn to the adjustment proposed by Sefton and Weale.[62] For Venezuela the imputed income adjustment is almost identical to the adjustment produced by El Serafy method at low interest rates (UC(2) in Table VI above). This is the case because the values of V_t assigned by the two methods are very similar at low interest rates. For Venezuela there is almost no difference between using the whole of the stock or just the stock dedicated to exports for the calculation of V_t, since the country exported most of the oil it produced. Note that if instead of using the stock targeted for exports we use the whole of the stock then, the value assigned to the resource corresponds precisely to the Hotelling Valuation Principle, that is $V_t = u_t Q_E \approx u_t Q = HVP$. We also know from Figures 4 and 5 that $HVP \approx PV2$ at low interest rates. As a consequence, the adjustments of El Serafy and Sefton and Weale are very similar for Venezuela

Mexico exported negligible amounts of oil until the mid-1970s consequently the expected gains from trade are very small and do not compensate the loss of the exhaustible resource until well into the 1970s as reported in Table VIII. Accordingly, for all the years Mexico restricted its oil exports, the adjustment to its conventional income in this model is negative and very similar to the adjustment produced by the net income price (which imputes no income at all to the reserves).

[TABLES VIII: Sefton and Weale results]

It must be noticed that the value of the adjustment depends highly on the rate of interest used in its computation, particularly in the case of Venezuela where the rate of return also affects the sign of the adjustment. At low interest rates Venezuelan expected gains from trade do not suffice to compensate for the loss of exhaustible resources, thus the adjustment is negative. At high interest rates the expected gains from trade exceed the loss of natural capital and the resulting adjustment is positive. If

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[61] El Serafy, S. (1989). 'The Proper Calculation Of Income From Depletable Natural Resources'. *Environmental Accounting For Sustainable Development: a UNEP- World Bank Symposium*. Y. J. Ahmad, S. E. Serafy and E. Lutz. Washington D.C., p.12-13.

[62] Sefton, J. A. and M. R. Weale (1996). 'The net national product and exhaustible resources: The effects of foreign trade.' *Journal of Public Economics* **61**: 21-47.

we believe that 6 per cent is a reasonable interest rate over the twentieth century then, as predicted by Sefton and Weale, the adjustment takes positive and negative values at different points in time.

The results of this model seem to indicate a preference of methodology depending on the actual use given to the resource. For a pure resource exporter, such as Venezuela, the user costs as proposed by El Serafy would be preferred over the net price. For an oil producer that uses the resource entirely for domestic production, such as Mexico during the period 1938-1970s, the net price will be preferred over the user costs method. A direct implication of Sefton and Weale´s approach is that an oil producer receives no benefit from owing a vast reserve of an exhaustible resource unless the country plans to export the resource. While the net price adjustment imputes an income to none of the stock, the user costs imputes an income to the whole of the stock and Sefton and Weale impute an income only to the exportable part of the stock.

5. Concluding remarks

As anyone who performs applied works knows, many assumptions are made in coming with answers. It is not unusual for one to feel a little uncomfortable with some of these assumptions and to wonder what would happen if they could be relaxed. In the calculations in this paper it was possible to relax the most common assumptions of value and depreciation methods used in environmental accounting.

One of the main conclusions of the exercises carried out is that the underlying assumptions regarding the behaviour of rents over time are crucial to the actual level of the adjustments. That comes as no surprise. What is new, however, is that the conclusions obtained in the theoretical literature about the bias of the different methods are also linked to these assumptions. Therefore, the biases of the methods, as commonly believed in the literature, only hold under the most restricted scenario of constant rents over time. The clearest example of this is the claim that the HVP leads to overvaluation, which is only true if compared with the valuation obtained using constant rents over time but not otherwise.

It was also found that the value of the resource is very much related to the life expectancy of the resource. In most theoretical exercises both the life expectancy of the resource (*n)* and the quantity extracted (*q)* are held constant at their initial levels. In those models capital gains/losses can only arise from changes in the price of the resource. In the case of our two countries the life expectancy of the resource varies due to changes in the pace of extraction and/or the finding of new reserves. As a consequence, a great deal of the variations in the value of the resource observed comes from these changes in the life expectancy of the resource, providing an alternative source of capital gains. This result is clearly exemplified by the importance of life expectancy in each and every calculation; n turns out to be the key variable. It is more important than the choice of rate of discount. Since the life expectancy of the resource is to a certain extent a pure management variable (change the pace of extraction), it leaves room to speculate about the different strategies followed by these two countries.

As a result of adopting the theoretical arguments spelt out by Sefton and Weale, it has been established that the net price and the user cost are not competing methods as such, but alternative adjustments to different scenarios. While the net price is the correct adjustment for closed economies, open economies need to impute an income to the stock targeted for exports; in the case of a pure resource exporter the user costs approximates this result quite reasonably as the results for Venezuela in section 4 have shown. This suggests a different type of adjustment for each of our two case studies. Since Mexico resembles the closed economy for the period 1938-1970s and Venezuela the pure resource exporter during the 20th century, the net price should be the method used to the adjustment of Mexican national accounts for the aforementioned period, whereas the user costs should be used for Venezuela. In fact, implementing the methodology proposed by Sefton and Weale avoid having to switch from one method to another when Mexico changed its policy in the 1970s, since their method is able to capture the change in policy.

The complication in ex post analysis is to distinguish the effects of our inability to anticipate the future accurately from the analytical failure of the models. Through the findings of this paper it can be argued that the difference between what is expected to happen and what actually did happen is for the most part due to a missing variable, namely technological change, and a misleading assumption, that is increasing scarcity, which is at the root of Hotelling's principle. These should serve as a caveat to the recommendations resulting from adjustments based on these models.

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Table I: Summary of theoretical methods

Method	Value assigned	Depreciation
Present Value	$V_t = \sum_{n=0}^{n=(R_t/q_t)} \frac{N_{t+n}}{(1+i)^n}$	$V_{t+1} - V_t$ = $\left[\sum_{n=0}^{n=(R_{1+t}/q_{t+1})} \frac{N_{t+1+n}}{(1+i)^n}\right] - \left[\sum_{n=0}^{n=(R_t/q_t)} \frac{N_{t+n}}{(1+i)^n}\right]$
Net Value	V_t = $(q_t+q_{t+1}+q_{t+2}+.....+q_{t+n})\ u_t$ = $u_t Q$	$-q_t u_t$ = $-q_t (p_t - mc_t)$ = $-N_t$
User Cost	$V_t = \sum_{n=0}^{n=(R_t/q_r)} \frac{N_t}{(1+i)^n}$	$-N_t/(1+i)^{n+1}$
Imputed Income	$V_t=u_tQ_E$	$-N_t +(V_t(i/(1+i)$ = $-N_t +(u_tQ_E(i/(1+i)$

Legend:
V_t = value of the resource in year *t*
q_t = amount extracted in year *t*
u_t = p_t-mc_t =Hotellin per unit rent in year *t*
$p_{t=}$ price in year *t*
mc_t= marginal cost of extraction in year *t*
N_t = total resource rent in year *t*
n_t = R_t/q_t= life expectancy of the resource in year *t*
R_t= resource reserves in year *t*
q_t = amount extracted in year *t*
Q = sum of all possible future quantities extracted
Q_e= stock of the resource targeted for exports

Table II: Accumulated oil production 1901-1985. Mexico and Venezuela

Accumulated oil production until	**Mexico** Mill. Barrels	**Venezuela** Mill. Barrels
1905	0.5	0
1915	127.24	0
1925	1,301.46	38.14
1935	1,765.63	1,148.14
1945	2,173.63	3,199.64
1955	2,871.08	8,945.04
1965	3,906.01	19,786.04
1975	5,562.74	31,934.04
1985	12,661.31	39,421.04
Oil reserves in 1985	70,900.00	29,236.00
Aggregated oil endowment 1905-1985	83,561.00	68,747.00

Sources: Rubio Varas (2002)

Table III-: Underlying assumptions for three implementations of the Present Value Method

Variable	***PV1*** *Theoretical definition*		***PV2*** *Common implementation*		***PV3*** *Alternative implementation*	
N { u { Price	Changes from t to $t+n$		Kept constant as in t		Changes from t to $t+n$	
N { u { Costs	Change from t to $t+n$		Kept constant as in t		Changes from t to $t+n$	
N { q Quantity	Changes from t to $t+n$		Kept constant as in t		Kept constant as in t	
Reserves (n)	Changes from t to $t+n$		Changes from t to $t+n$*		Changes from t to $t+n$	
Social discount	Kept constant		Kept constant		Kept constant	
Algebraically	$V_t = \sum_{n=0}^{n} \frac{N_{t+n}}{(1+i)^n}$		$V_t = \sum_{n=0}^{n} \frac{N_t}{(1+i)^n}$		$V_t = q_t \sum_{n=0}^{n} \frac{u_{t+n}}{(1+i)^n}$	
It generates…	…the present value of the *aggregated rents generated every year to come*		…the present value of the *aggregated rents generated in the current year*		…the present value of the *current year's production*	
	Mexico max $t+n$=1987 t=1935-1972	Venezuela max $t+n$=1987 t =1920-1972	Mexico t =1920-1987	Venezuela t =1935-1985	Mexico max $t+n$=1987 t =1935-1972	Venezuela max $t+n$=1985 t =1920-1972

* When this equation is implemented for forecasting purposes, reserves are normally kept to the level of the initial year through the period. So the present value for 1921 would be discounted for 20 years, for 1922 for 19 and so on and so forth. In contrary in this historical exercise, additions to reserves are allowed as they occurred. Every year is a starting point in itself, with its own production, prices, costs and reserves available for the calculation of the present value. This produces a different path from the forecast exercises

Table IV : Change in value of Venezuelan oil resources 1920-1984 ($V_{t+1}-V_t$)

t	t+1	$PV1_{t+1}-PV1_t$ i=3 Mll.US $	i=6 Mll.US $	i=15 Mll.US $	$PV2_{t+1}-PV2_t$ i=3 Mll.US $	i=6 Mll.US $	i=15 Mll.US $	$PV3_{t+1}-PV3_t$ i=3 Mll.US $	i=6 Mll.US $	i=15 Mll.US $	Net price Nt Mll.US $
1920	1921	738	423	72	(-4)	(-2)	(-1)	9	6	3	
1921	1922	2.894	1.284	121	3	3	2	17	10	5	
1922	1923	3.665	1.303	100	37	25	12	44	26	12	
1923	1924	11.459	2.894	122	148	91	41	196	81	29	1
1924	1925	(-18.137)	(-5.328)	(-139)	175	157	96	(-62)	40	55	6
1925	1926	(-683)	(-371)	(-12)	265	223	143	84	81	65	19
1926	1927	(-177)	(-111)	2	(-64)	(-32)	3	108	100	77	40
1927	1928	(-164)	(-130)	(-12)	144	153	147	168	164	146	42
1928	1929	(-265)	(-239)	(-105)	(-63)	(-20)	53	(-85)	(-54)	3	72
1929	1930	70	61	17	215	181	113	41	28	4	109
1930	1931	13	12	(-22)	(-246)	(-235)	(-203)	(-76)	(-77)	(-76)	101
1931	1932	62	57	20	319	268	173	21	12	(-0)	49
1932	1933	228	173	25	(-675)	(-594)	(-430)	25	(-1)	(-38)	110
1933	1934	1.930	1.397	401	592	460	258	584	403	162	46
1934	1935	988	702	194	156	116	60	284	191	68	78
1935	1936	572	437	146	113	91	55	138	95	32	85
1936	1937	816	617	206	98	78	47	505	365	157	110
1937	1938	1.009	772	261	(-435)	(-349)	(-210)	177	125	39	124
1938	1939	1.324	1.014	370	(-262)	(-210)	(-127)	470	350	166	95
1939	1940	10.808	4.413	956	474	273	77	827	437	75	77
1940	1941	(-2.077)	(-751)	222	866	687	400	561	540	366	83
1941	1942	67.850	19.623	1.982	(-1.008)	(-894)	(-561)	5.399	1.639	(-281)	138
1942	1943	(-23.462)	(-4.284)	434	711	514	262	(-1.118)	61	361	61
1943	1944	(-38.810)	(-8.982)	(-135)	802	762	508	(-1.900)	(-48)	708	95
1944	1945	(-3.856)	(-1.636)	309	349	363	287	757	873	732	166
1945	1946	(-2.858)	(-1.342)	273	821	748	542	588	763	773	210
1946	1947	(-926)	(-290)	447	2.139	1.844	1.264	532	639	673	293
1947	1948	(-33)	238	484	3.884	3.310	2.235	864	841	722	486
1948	1949	4.325	3.131	1.058	(-515)	(-608)	(-611)	1.128	677	108	827
1949	1950	(-1.913)	(-1.045)	116	532	622	620	219	421	561	712
1950	1951	(-314)	(-11)	339	179	250	294	954	921	764	829
1951	1952	(-388)	(-81)	318	701	702	622	147	268	394	891
1952	1953	5.102	3.860	1.579	2.000	1.460	659	1.914	1.290	425	1.011
1953	1954	1.500	1.297	816	1.229	1.029	672	1.318	1.077	669	1.063
1954	1955	1.372	1.221	809	2.875	2.407	1.572	2.422	1.996	1.260	1.163
1955	1956	1.263	1.099	681	2.549	2.134	1.394	2.803	2.296	1.414	1.397
1956	1957	1.579	1.236	649	5.254	4.399	2.873	3.387	2.704	1.563	1.604
1957	1958	13.917	9.006	2.507	(-1.887)	(-2.002)	(-1.818)	9.976	6.045	1.111	2.031
1958	1959	(-494)	(-2)	488	(-3.038)	(-2.307)	(-1.228)	1.368	1.362	937	1.703
1959	1960	7.302	5.176	2.203	(-910)	(-753)	(-482)	9.807	6.848	2.617	1.550
1960	1961	(-60)	541	1.149	383	498	547	871	1.272	1.281	1.480
1961	1962	(-173)	472	1.196	1.530	1.482	1.235	4.135	3.863	2.786	1.588
1962	1963	7.838	6.026	3.089	(-157)	(-133)	(-89)	12.055	9.062	4.220	1.810
1963	1964	(-111)	470	1.123	6.866	6.026	4.323	2.080	2.331	2.127	1.261
1964	1965	5.801	4.520	2.251	(-253)	(-217)	(-148)	10.606	8.156	3.915	1.967
1965	1966	5.361	4.383	2.445	(-638)	(-546)	(-374)	7.400	5.912	3.102	1.944
1966	1967	(-422)	386	1.279	(-446)	(-178)	180	3.188	3.605	3.335	1.885
1967	1968	(-523)	326	1.372	(-733)	(-433)	13	1.380	2.295	2.963	1.971
1968	1969	9.929	8.292	4.997	(-707)	(-620)	(-447)	15.603	12.918	7.763	2.043
1969	1970	(-238)	840	2.330	(-618)	(-347)	70	3.198	4.340	5.332	1.969
1970	1971	14.396	12.358	8.067	4.640	4.120	3.048	20.771	17.558	11.355	2.089
1971	1972	28.140	23.410	13.363	1.433	1.007	315	36.551	29.169	16.177	2.648
1972	1973				25.006	19.926	11.535				2.653
1973	1974				97.221	78.699	48.142				4.090
1974	1975				(-8.241)	(-11.424)	(-11.969)				10.878
1975	1976				2.123	1.668	971				8.668
1976	1977				21.012	15.256	7.732				8.740
1977	1978				(-10.750)	(-9.488)	(-6.428)				9.734
1978	1979				82.214	66.861	40.977				8.800
1979	1980				109.836	78.509	38.944				14.565
1980	1981				47.484	30.739	12.840				19.554
1981	1982				(-14.823)	(-31.342)	(-29.018)				21.103
1982	1983				(-40.709)	(-34.870)	(-20.262)				16.848
1983	1984				142.780	91.185	41.910				10.127

Notas:Numbers in parenthesis indicate depreciation (negative change in value), except forthe net price, in absolute values

Table V: Change in value of Mexican oil resources 1935-1987 ($V_{t+1}-V_t$)

t	t+1	$PV1_{t+1}-PV1_t$			$PV2_{t+1}-PV2_t$			$PV3_{t+1}-PV3_t$			
		i=3 Mll.US $	i=6 Mll.US $	I=15 Mll.US $	i=3 Mll.US $	i=6 Mll.US $	i=15 Mll.US $	i=3 Mll.US $	i=6 Mll.US $	i=15 Mll.US $	Net price Mll.US $
1935	1936	55	66	31	(-66)	(-44)	(-20)	39	37	16	31
1936	1937	(-290)	(-86)	21	426	327	182	85	93	56	29
1937	1938	424	219	31	(-224)	(-173)	(-98)	(-95)	(-80)	(-50)	43
1938	1939	(-465)	(-192)	(-5)	(-146)	(-94)	(-40)	(-66)	(-5)	17	26
1939	1940	306	184	51	(-77)	(-61)	(-35)	136	85	25	20
1940	1941	187	136	58	7	5	3	40	35	19	17
1941	1942	740	395	94	(-52)	(-47)	(-32)	(-45)	(-49)	(-27)	17
1942	1943	666	352	98	13	7	3	158	92	34	13
1943	1944	41.321	15.849	1.121	(-66)	(-53)	(-30)	4.157	1.665	166	13
1944	1945	(-36.280)	(-13.522)	(-736)	(-91)	(-59)	(-27)	(-2.884)	(-983)	30	9
1945	1946	(-5.354)	(-2.217)	(-91)	151	117	66	(-811)	(-251)	89	5
1946	1947	(-317)	(-81)	101	60	54	37	149	176	155	14
1947	1948	(-31)	47	109	544	436	262	58	84	99	17
1948	1949	349	229	101	286	206	103	179	128	71	38
1949	1950	(-236)	(-98)	35	450	386	257	112	131	124	48
1950	1951	113	82	43	257	194	104	118	94	58	85
1951	1952	1.949	1.061	201	379	256	111	735	396	71	99
1952	1953	4.905	2.599	437	(-569)	(-448)	(-261)	1.084	542	48	112
1953	1954	9.970	5.176	840	505	374	200	2.471	1.346	291	58
1954	1955	376	416	181	18	23	21	373	273	101	77
1955	1956	29.253	15.056	2.325	160	111	53	4.178	2.188	364	80
1956	1957	350.563	167.604	20.833	606	414	196	31.788	15.245	1.915	86
1957	1958	305.208	146.540	18.615	(-258)	(-190)	(-100)	32.206	15.559	2.029	112
1958	1959	20.915	20.170	6.450	(-409)	(-291)	(-147)	4.390	3.217	857	98
1959	1960	2.200.000	1.016.000	114.707	(-442)	(-341)	(-192)	240.044	110.890	12.627	79
1960	1961	87.576	82.319	24.675	1.026	761	407	35.007	21.367	4.429	53
1961	1962	90.148	87.201	28.314	263	209	121	27.683	18.788	4.611	107
1962	1963	1.632.000	824.000	120.161	(-62)	(-46)	(-25)	214.431	108.015	15.855	124
1963	1964	(-1.440.000)	(-631.137)	(-50.191)	(-161)	(-91)	(-27)	(-178.096)	(-77.652)	(-5.979)	121
1964	1965	98.495	103.845	43.044	(-225)	(-156)	(-75)	21.219	17.930	6.404	118
1965	1966	1.784.000	976.000	182.769	(-199)	(-152)	(-84)	247.168	135.711	25.450	108
1966	1967	(-1.576.000)	(-751.668)	(-76.305)	(-135)	(-80)	(-24)	(-161.359)	(-72.208)	(-4.072)	97
1967	1968	1.888.000	1.096.000	241.729	(-268)	(-208)	(-119)	330.069	191.849	42.319	95
1968	1969	164.390	189.689	101.775	136	117	77	71.846	57.126	22.598	78
1969	1970	(-1.720.000)	(-896.000)	(-116.039)	(-186)	(-126)	(-53)	(-252.004)	(-127.685)	(-13.534)	90
1970	1971	2.064.000	1.312.000	367.657	821	658	397	347.826	220.594	62.317	84
1971	1972	179.569	225.857	154.714	330	285	194	67.303	62.367	33.915	140
1972	1973				2.940	2.382	1.462				169
1973	1974				19.541	16.274	10.511				376
1974	1975				6.728	5.864	4.118				1.922
1975	1976				32.670	22.624	10.207				2.047
1976	1977				33.043	26.577	15.960				2.230
1977	1978				84.184	36.228	8.841				4.436
1978	1979				107.139	65.227	29.325				5.371
1979	1980				391.568	231.212	102.720				9.145
1980	1981				269.077	157.728	69.887				21.110
1981	1982				529.906	334.033	152.870				12.956
1982	1983				479.074	289.440	129.749				12.521
1983	1984				(-689.048)	(-419.063)	(-188.989)				51.991
1984	1985				638.455	386.966	173.629				9.075
1985	1986				(-4.979)	(-6.774)	(-3.751)				13.319
1986	1987				313.457	190.106	85.620				5.694

Notes: Numbers in parenthesis indicate depreciation (negative change in value), except for the net price, which is presented in absolute value

Table VI: El Serafy's user costs (net change in value $V_t(i/1+i) - N_t$) for Venezuelan oil resources, 1920-1985

Year	UC(1)			UC(2)			UC(3)		
	i=3	i=6	i=15	i=3	i=6	i=15	i=3	i=6	i=15
	Mll.US $	Mll.US $	Mll.US $	Mll.US $	Mll.US $	Mll.US $	Mll.US $	Mll.US $	Mll.US $
1920	19	27	25				0,1	0,1	0,02
1921	39	46	33				0,3	0,4	0,4
1922	128	117	52				1	1	1
1923	236	186	65	(-0,2)	(-0,1)		1	2	2
1924	574	348	79	(-1)	(-0,3)		2	1	0
1925	33	48	47	(-9)	(-4)	(-1)	(-13)	(-10)	(-6)
1926	(-9)	8	24	(-22)	(-12)	(-2)	(-31)	(-25)	(-17)
1927	(-16)	0	22	(-26)	(-17)	(-4)	(-30)	(-22)	(-10)
1928	(-51)	(-36)	(-10)	(-52)	(-38)	(-16)	(-56)	(-43)	(-21)
1929	(-99)	(-88)	(-63)	(-94)	(-79)	(-48)	(-98)	(-86)	(-60)
1930	(-99)	(-87)	(-64)	(-90)	(-71)	(-37)	(-99)	(-87)	(-63)
1931	(-42)	(-32)	(-14)	(-41)	(-31)	(-14)	(-44)	(-36)	(-20)
1932	(-59)	(-49)	(-34)	(-51)	(-36)	(-14)	(-63)	(-55)	(-42)
1933	(-12)	5	23	(-26)	(-17)	(-6)	(-23)	(-12)	3
1934	9	44	46	(-47)	(-28)	(-6)	(-44)	(-25)	(-9)
1935	30	71	63	(-49)	(-28)	(-6)	(-42)	(-21)	(-7)
1936	39	86	74	(-53)	(-31)	(-7)	(-45)	(-24)	(-11)
1937	63	127	108	(-66)	(-39)	(-8)	(-45)	(-14)	1
1938	126	205	178	(-54)	(-31)	(-7)	(-14)	22	36
1939	183	276	245	(-44)	(-25)	(-5)	18	60	75
1940	492	495	363	(-36)	(-16)	(-2)	36	78	79
1941	376	401	337	(-66)	(-32)	(-4)	(-3)	54	72
1942	2.430	1.558	673	(-18)	(-6)	(-0)	232	224	112
1943	1.712	1.282	695	(-32)	(-11)	(-1)	164	193	125
1944	511	710	607	(-79)	(-39)	(-5)	38	119	146
1945	355	577	604	(-113)	(-62)	(-11)	17	125	198
1946	188	421	556	(-172)	(-103)	(-24)	(-49)	85	216
1947	(-32)	213	421	(-303)	(-191)	(-52)	(-227)	(-72)	110
1948	(-374)	(-115)	143	(-531)	(-345)	(-102)	(-543)	(-366)	(-137)
1949	(-133)	166	396	(-431)	(-265)	(-66)	(-395)	(-212)	(-7)
1950	(-305)	(-6)	295	(-532)	(-346)	(-102)	(-505)	(-305)	(-51)
1951	(-377)	(-69)	276	(-589)	(-394)	(-126)	(-540)	(-315)	(-14)
1952	(-508)	(-192)	199	(-688)	(-474)	(-164)	(-655)	(-419)	(-82)
1953	(-411)	(-37)	352	(-682)	(-444)	(-131)	(-652)	(-399)	(-79)
1954	(-468)	(-66)	359	(-747)	(-485)	(-143)	(-713)	(-438)	(-91)
1955	(-661)	(-234)	230	(-897)	(-583)	(-172)	(-876)	(-558)	(-161)
1956	(-832)	(-381)	112	(-1.030)	(-669)	(-197)	(-1.002)	(-636)	(-183)
1957	(-1.213)	(-739)	(-231)	(-1.304)	(-848)	(-250)	(-1.331)	(-910)	(-407)
1958	(-479)	96	425	(-1.030)	(-632)	(-158)	(-712)	(-239)	67
1959	(-341)	254	641	(-966)	(-610)	(-166)	(-519)	(-9)	342
1960	(-58)	622	999	(-922)	(-582)	(-158)	(-163)	449	753
1961	(-168)	551	1.040	(-1.019)	(-663)	(-195)	(-246)	412	812
1962	(-395)	362	975	(-1.196)	(-800)	(-256)	(-347)	409	954
1963	(-153)	718	1.391	(-1.188)	(-794)	(-254)	17	936	1.518
1964	(-816)	(-170)	418	(-1.339)	(-922)	(-320)	(-632)	84	638
1965	(-624)	109	735	(-1.324)	(-911)	(-316)	(-300)	569	1.172
1966	(-409)	414	1.112	(-1.284)	(-884)	(-306)	(-27)	961	1.634
1967	(-507)	354	1.193	(-1.382)	(-979)	(-368)	(-19)	1.080	1.984
1968	(-595)	302	1.300	(-1.476)	(-1.076)	(-439)	(-52)	1.137	2.298
1969	(-231)	843	2.026	(-1.423)	(-1.037)	(-423)	477	1.943	3.385
1970	(-335)	797	2.233	(-1.537)	(-1.153)	(-511)	474	2.092	3.984
1971	(-448)	971	2.783	(-1.948)	(-1.462)	(-647)	556	2.582	4.983
1972	423	2.332	4.615	(-1.872)	(-1.365)	(-557)	1.683	4.319	7.207
1973				(-2.625)	(-1.707)	(-503)			
1974				(-6.581)	(-4.040)	(-1.011)			
1975				(-4.715)	(-2.580)	(-466)			
1976				(-4.732)	(-2.589)	(-468)			
1977				(-5.080)	(-2.701)	(-450)			
1978				(-4.459)	(-2.304)	(-354)			
1979				(-7.829)	(-4.284)	(-774)			
1980				(-9.619)	(-4.829)	(-683)			
1981				(-9.785)	(-4.639)	(-557)			
1982				(-6.001)	(-2.197)	(-127)			
1983				(-4.465)	(-1.457)	(-61)			
1984				(-4.506)	(-1.349)	(-44)			
1985				(-3.420)	(-887)	(-19)			

Notes:Numbers in parenthesis indicate depreciation (negative change in value)

UC(1), UC(2) and UC(3) correspond to the user costs generated by PV1,PV2 and PV3 respectively.

TableVII: El Serafy's user costs (net change in value $V_t(i/1+i)-N_t$) for Mexican oil resources, 1935-1987

Year	UC(1)			UC(2)			UC(3)		
	i=3	i=6	i=15	i=3	i=6	i=15	i=3	i=6	i=15
	Mll.US $	Mll.US $	Mll.US $	Mll.US $	Mll.US $	Mll.US $	Mll.US $	Mll.US $	Mll.US $
1935	16	62	27	(-18)	(-5)	(-1)	(-6)	18	8
1936	21	68	33	(-17)	(-5)	(-1)	(-3)	23	13
1937	(-6)	39	11	(-32)	(-11)	(-1)	(-24)	3	(-4)
1938	15	56	26	(-17)	(-6)	(-0)	(-8)	12	3
1939	12	43	27	(-13)	(-5)	(-1)	(-3)	15	10
1940	22	57	38	(-9)	(-4)	(-1)	5	24	18
1941	28	70	49	(-10)	(-4)	(-1)	6	28	22
1942	44	97	66	(-7)	(-2)	(-0)	9	30	23
1943	54	117	78	(-7)	(-2)	(-0)	11	35	27
1944	519	1.018	228	(-5)	(-1)	0	64	133	52
1945	129	256	136	(-3)	(-1)	0	39	81	60
1946	56	122	115	(-9)	(-3)	(-0)	23	58	63
1947	48	112	123	(-12)	(-6)	(-1)	22	62	78
1948	5	60	81	(-34)	(-17)	(-3)	(-15)	21	42
1949	(-3)	43	58	(-32)	(-13)	(-2)	(-20)	9	26
1950	(-43)	(-3)	21	(-56)	(-28)	(-6)	(-53)	(-22)	3
1951	(-54)	(-12)	13	(-64)	(-31)	(-6)	(-64)	(-30)	(-3)
1952	(-36)	35	26	(-69)	(-29)	(-5)	(-65)	(-21)	(-7)
1953	75	218	119	(-46)	(-19)	(-3)	(-13)	46	35
1954	182	433	174	(-51)	(-20)	(-3)	2	84	38
1955	174	413	178	(-49)	(-20)	(-3)	7	89	44
1956	606	1.258	475	(-52)	(-20)	(-3)	64	206	85
1957	5.462	10.720	3.167	(-65)	(-22)	(-2)	483	1.044	310
1958	9.744	19.028	5.608	(-58)	(-19)	(-2)	949	1.938	588
1959	10.350	20.189	6.469	(-47)	(-16)	(-2)	1.062	2.139	719
1960	39.935	77.660	21.457	(-31)	(-10)	(-1)	4.318	8.442	2.392
1961	42.278	82.265	24.621	(-63)	(-21)	(-2)	4.886	9.597	2.915
1962	44.802	87.185	28.297	(-73)	(-26)	(-3)	5.417	10.644	3.500
1963	68.733	133.689	43.974	(-71)	(-25)	(-3)	8.566	16.761	5.572
1964	50.353	97.967	37.430	(-71)	(-28)	(-4)	6.307	12.369	4.794
1965	53.387	103.854	43.054	(-66)	(-27)	(-4)	6.839	13.393	5.639
1966	81.897	159.250	66.905	(-59)	(-24)	(-3)	10.803	21.086	8.970
1967	60.006	116.705	56.954	(-60)	(-26)	(-4)	8.702	17.001	8.441
1968	92.044	178.952	88.500	(-49)	(-22)	(-4)	14.306	27.877	13.977
1969	97.558	189.678	101.764	(-57)	(-26)	(-5)	15.959	31.099	16.914
1970	71.488	139.010	86.634	(-55)	(-28)	(-6)	12.246	23.878	15.154
1971	109.571	213.072	134.534	(-92)	(-46)	(-10)	18.615	36.308	23.227
1972	116.121	225.828	154.685	(-112)	(-59)	(-14)	20.403	39.810	27.621
1973				(-250)	(-132)	(-30)			
1974				(-1.323)	(-757)	(-205)			
1975				(-1.799)	(-1.072)	(-316)			
1976				(-1.952)	(-751)	(-98)			
1977				(-2.795)	(-1.235)	(-206)			
1978				(-2.681)	(-129)	(-1)			
1979				(-4.600)	(-263)	(-2)			
1980				(-11.239)	(-574)	(-3)			
1981				(-15.046)	(-726)	(-4)			
1982				(-16.662)	(-1.335)	(-15)			
1983				(-14.854)	(-1.064)	(-10)			
1984				(-13.791)	(-988)	(-9)			
1985				(-15.955)	(-1.080)	(-10)			
1986				(-6.405)	(-346)	(-2)			
1987				(-8.463)	(-542)	(-4)			

Notes:Numbers in parenthesis indicate depreciation (negative change in value)
UC(1), UC(2) and UC(3) correspond to the user costs generated by PV1,PV2 and PV3 respectively.

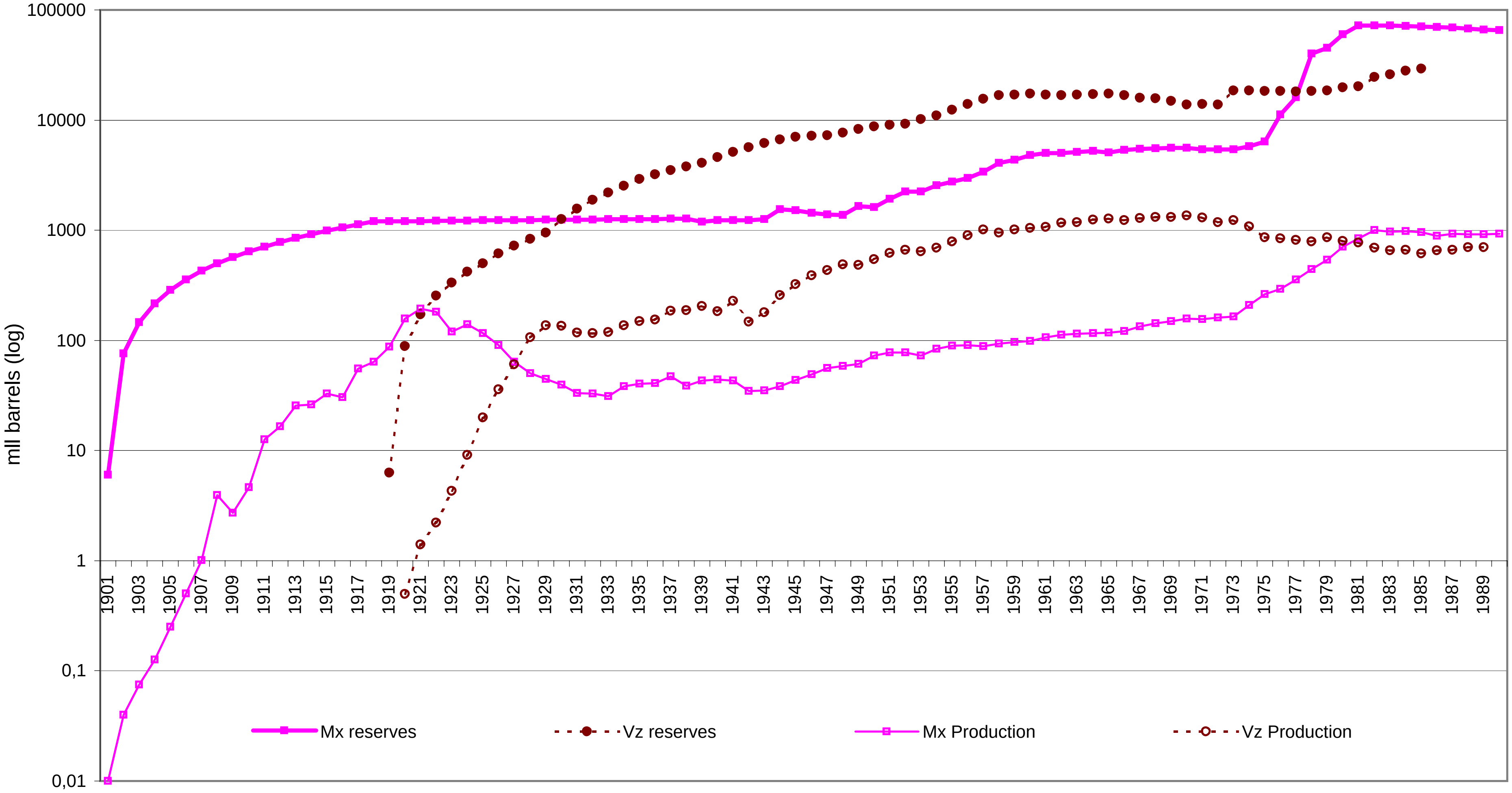
TableVIII: Sefton and Weale adjustment, imputed value to the stock targeted for exports.

Year	Venezuela 1921-1985 -Nt+Vt(i/1+i) i=3% Mll.US $	Venezuela i=6% Mll.US $	Venezuela i=15% Mll.US $	Mexico 1935-1985 -Nt+Vt(i/1+i) i=3% Mll.US $	Mexico i=6% Mll.US $	Mexico i=15% Mll.US $
1921	0	(-1)	(-2)			
1922	(-0)	(-1)	(-3)			
1923	0	1	4			
1924	4	13	38			
1925	(-5)	8	43			
1926	(-16)	6	65			
1927	(-23)	(-4)	45			
1928	(-48)	(-26)	34			
1929	(-90)	(-68)	(-12)			
1930	(-85)	(-57)	16			
1931	(-38)	(-22)	22			
1932	(-46)	(-21)	47			
1933	(-23)	(-7)	35			
1934	(-37)	3	110			
1935	(-37)	8	130	(-15)	(-0)	41
1936	(-40)	9	143	(-16)	(-3)	31
1937	(-50)	12	181	(-37)	(-21)	21
1938	(-40)	11	148	(-23)	(-18)	(-2)
1939	(-33)	9	122	(-16)	(-11)	2
1940	(-15)	50	223	(-11)	(-8)	2
1941	(-38)	57	311	(-15)	(-12)	(-6)
1942	14	84	274	(-12)	(-11)	(-8)
1943	6	102	360	(-13)	(-12)	(-12)
1944	(-42)	74	388	(-9)	(-9)	(-8)
1945	(-79)	45	377	(-5)	(-5)	(-5)
1946	(-137)	10	406	(-14)	(-13)	(-12)
1947	(-254)	(-34)	555	(-19)	(-18)	(-17)
1948	(-460)	(-113)	819	(-47)	(-42)	(-26)
1949	(-369)	(-44)	827	(-48)	(-45)	(-36)
1950	(-456)	(-105)	839	(-77)	(-70)	(-50)
1951	(-526)	(-181)	746	(-93)	(-88)	(-73)
1952	(-614)	(-239)	768	(-99)	(-87)	(-55)
1953	(-596)	(-155)	1.029	(-73)	(-70)	(-63)
1954	(-653)	(-171)	1.123	(-81)	(-78)	(-69)
1955	(-786)	(-210)	1.339	(-76)	(-73)	(-64)
1956	(-915)	(-266)	1.480	(-82)	(-78)	(-66)
1957	(-1.168)	(-353)	1.835	(-108)	(-105)	(-97)
1958	(-875)	(-93)	2.006	(-98)	(-98)	(-97)
1959	(-828)	(-146)	1.685	(-79)	(-79)	(-79)
1960	(-792)	(-142)	1.602	(-53)	(-52)	(-51)
1961	(-887)	(-226)	1.551	(-101)	(-96)	(-80)
1962	(-1.087)	(-405)	1.428	(-117)	(-111)	(-93)
1963	(-1.081)	(-407)	1.405	(-114)	(-109)	(-93)
1964	(-1.212)	(-499)	1.414	(-112)	(-106)	(-91)
1965	(-1.212)	(-522)	1.333	(-104)	(-99)	(-87)
1966	(-1.172)	(-499)	1.308	(-91)	(-85)	(-70)
1967	(-1.299)	(-664)	1.040	(-90)	(-85)	(-73)
1968	(-1.374)	(-743)	954	(-75)	(-72)	(-63)
1969	(-1.353)	(-771)	792	(-86)	(-83)	(-73)
1970	(-1.487)	(-941)	527	(-78)	(-73)	(-59)
1971	(-1.847)	(-1.120)	834	(-136)	(-132)	(-122)
1972	(-1.769)	(-993)	1.091	(-166)	(-163)	(-156)
1973	(-2.429)	(-863)	3.347	(-370)	(-365)	(-350)
1974	(-5.930)	(-1.263)	11.278	(-1.897)	(-1.873)	(-1.808)
1975	(-3.859)	775	13.228	(-2.418)	(-2.274)	(-1.889)
1976	(-3.883)	759	13.229	(-2.944)	(-2.679)	(-1.967)
1977	(-4.275)	875	14.714	(-3.839)	(-3.263)	(-1.715)
1978	(-3.746)	1.022	13.832	(-2.320)	572	8.341
1979	(-6.779)	566	20.303	(-3.264)	2.333	17.372
1980	(-7.923)	3.049	32.530	(-4.848)	11.846	56.704
1981	(-8.128)	4.112	37.002	(-3.439)	21.832	89.735
1982	(-3.175)	9.761	44.521	(-3.957)	23.356	96.746
1983	(-1.514)	10.397	42.402	(-817)	26.214	98.846
1984	(-260)	14.205	53.073	(-1.085)	23.704	90.313
1985	1.184	15.246	53.028	(-2.168)	25.713	100.627

Notes: Numbers in parenthesis indicate depreciation (negative change in value)

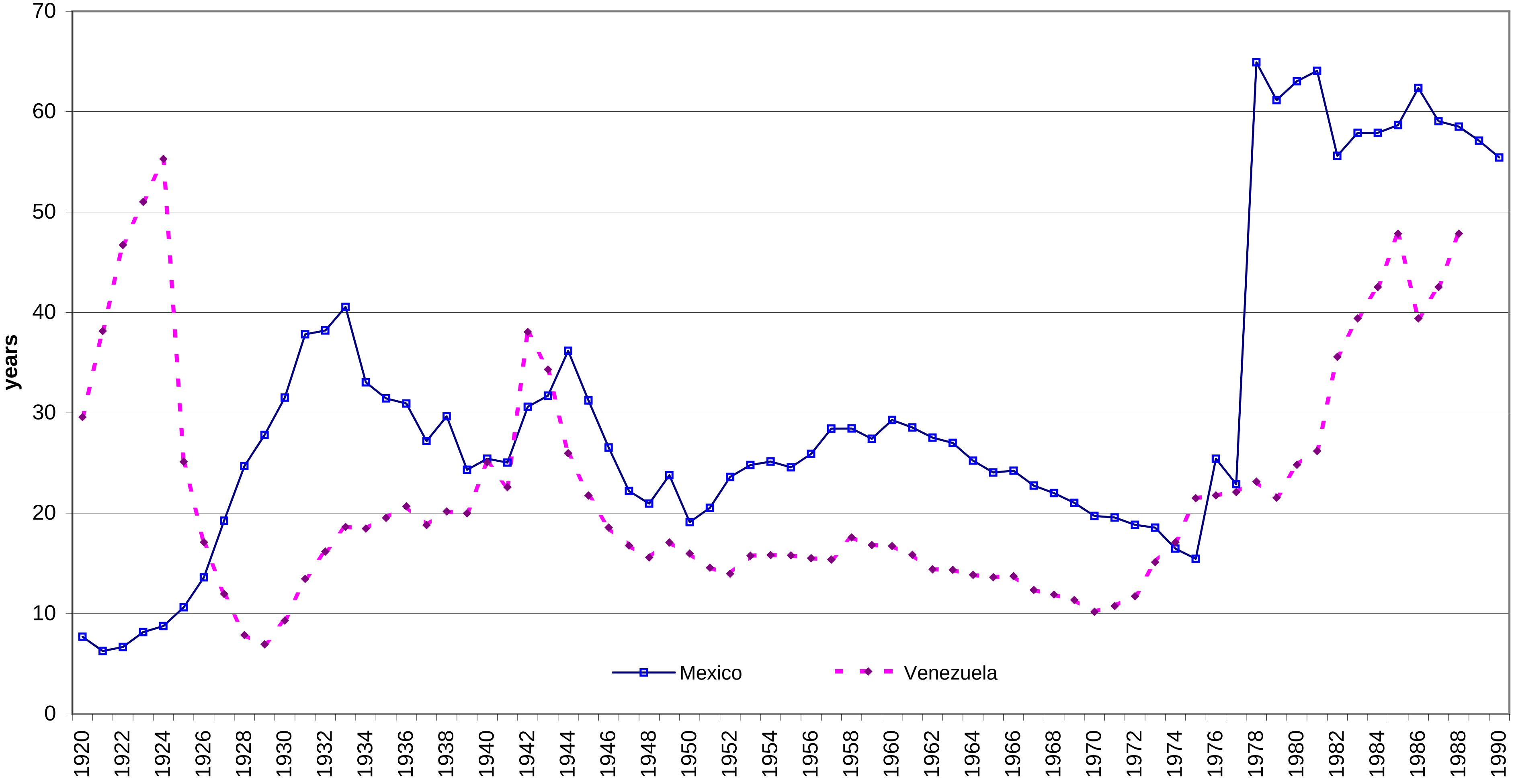
The value of the resource is given by $V_t=uQ_e$

Figure 1: Petroleum reserves and production. Mexico and Venezuela 1901-1989



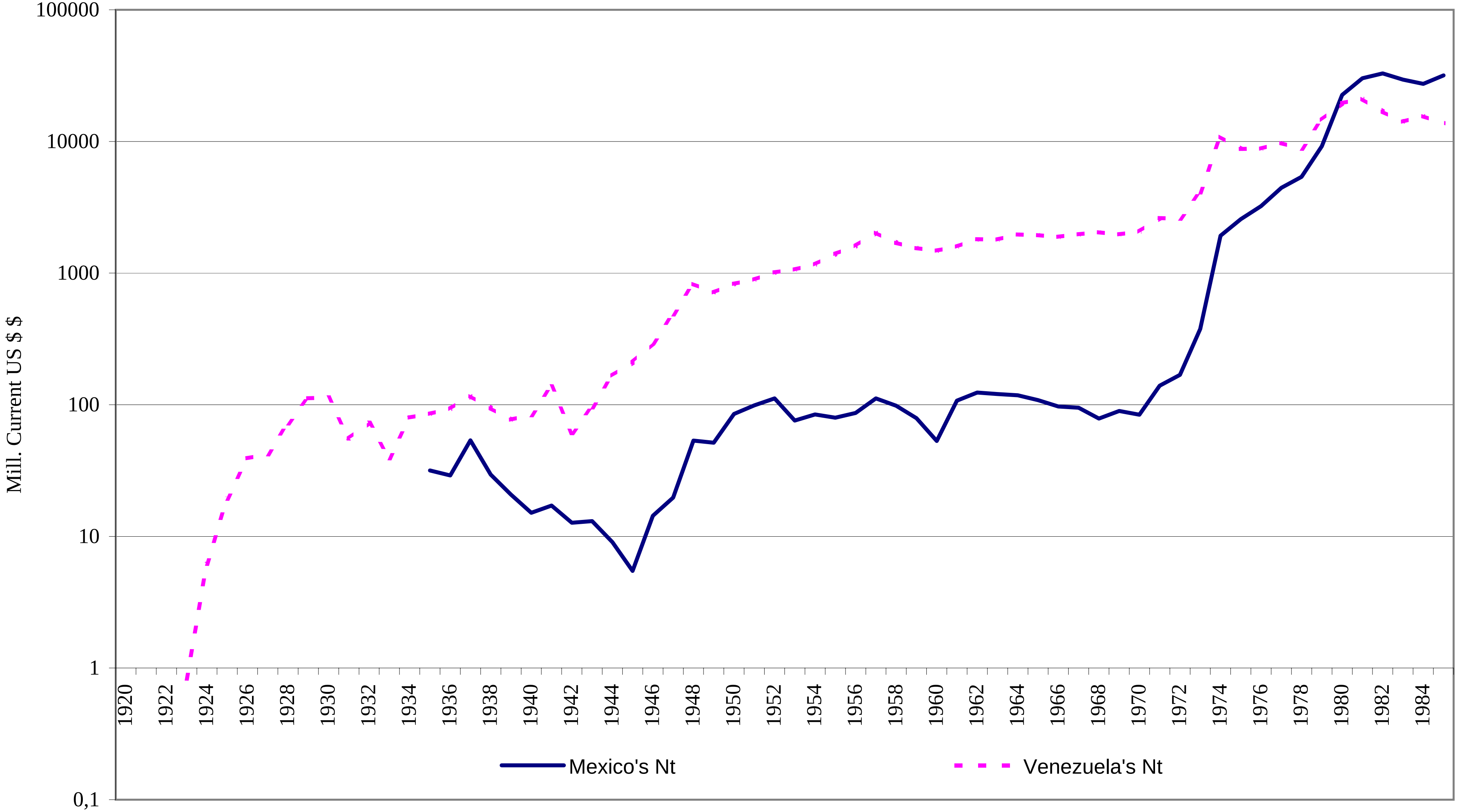
Data compiled by Rubio Varas (2002)

Figure 2: Life expectancy of oil reserves (n=R/q). Mexico and Venezuela.1920-1989



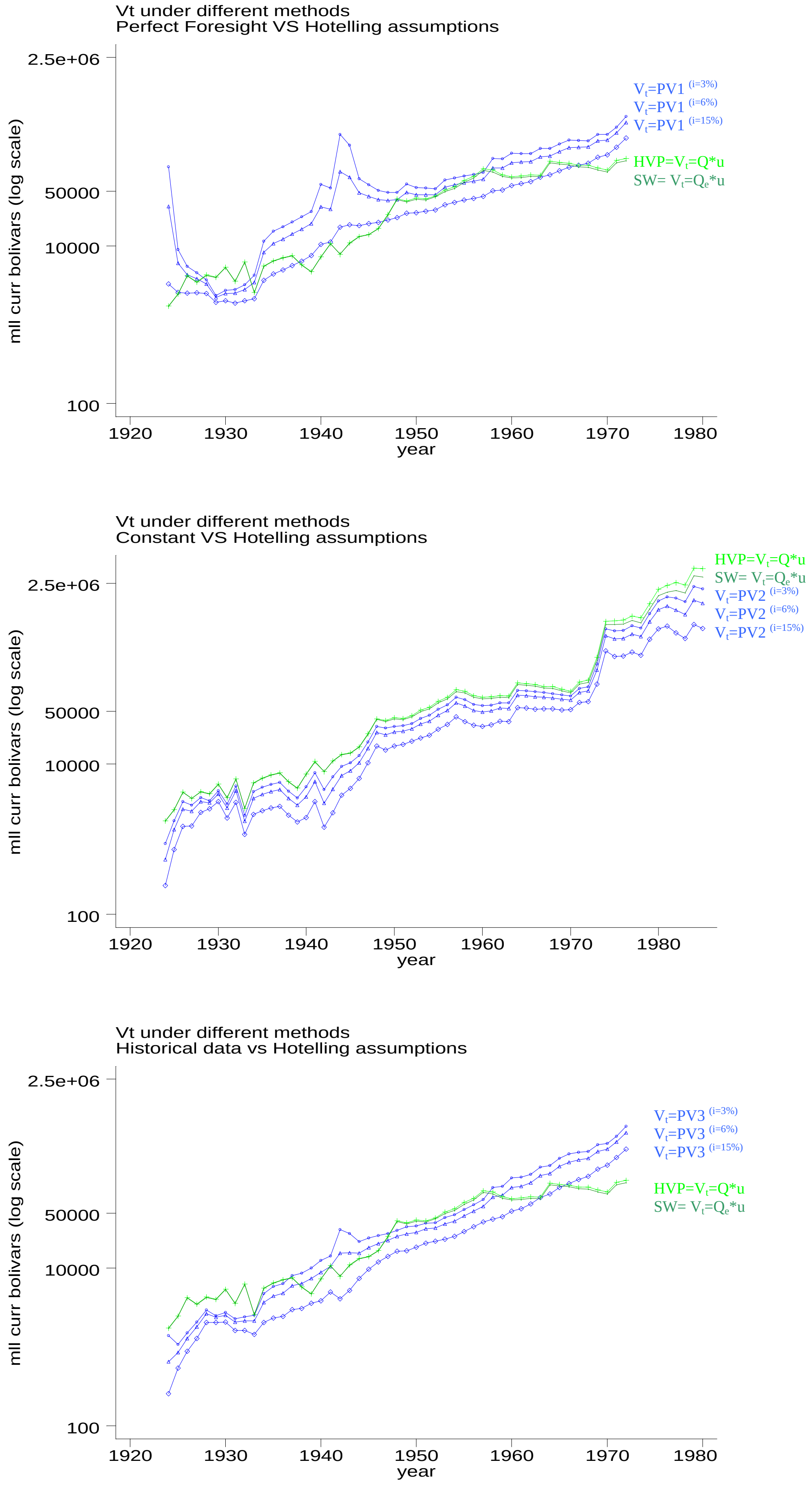
Data compiled by Rubio Varas (2002)

Figure 3: Petroleum rent (Nt). Mexico and Venezuela 1920s-1980s



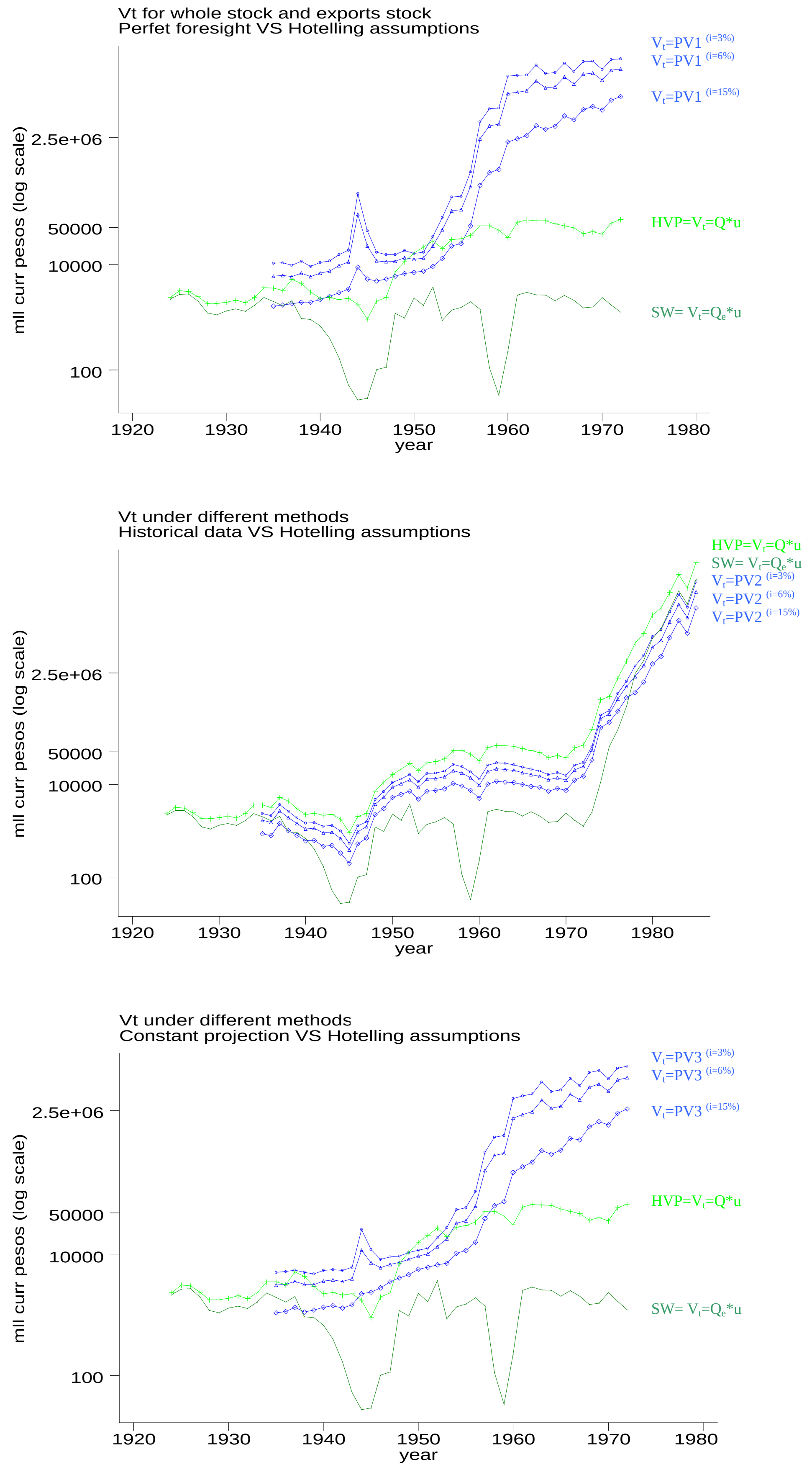
Data compiled by Rubio Varas (2002)

Figure 4: Contrasts of the values assigned to the petroleum assets according to different methods and implementations. Venezuela 1920s-1980s



Notes: PV1, PV2 and PV3 as defined in Table III and calculated for three different social discount rates:

Figure 5: Contrasts of the values assigned to the petroleum assets according to different methods and implementations. México 1930s-1980s



Notes: PV1, PV2 and PV3 as defined in Table III and calculated for three different social discount rates; HVP and SW values are the same in all three panels to facilitate the contrast of values.

Figure 6: Venezuela: 1920-1985: Porportion of the net receipt that should be accounted (discounted) as user cost

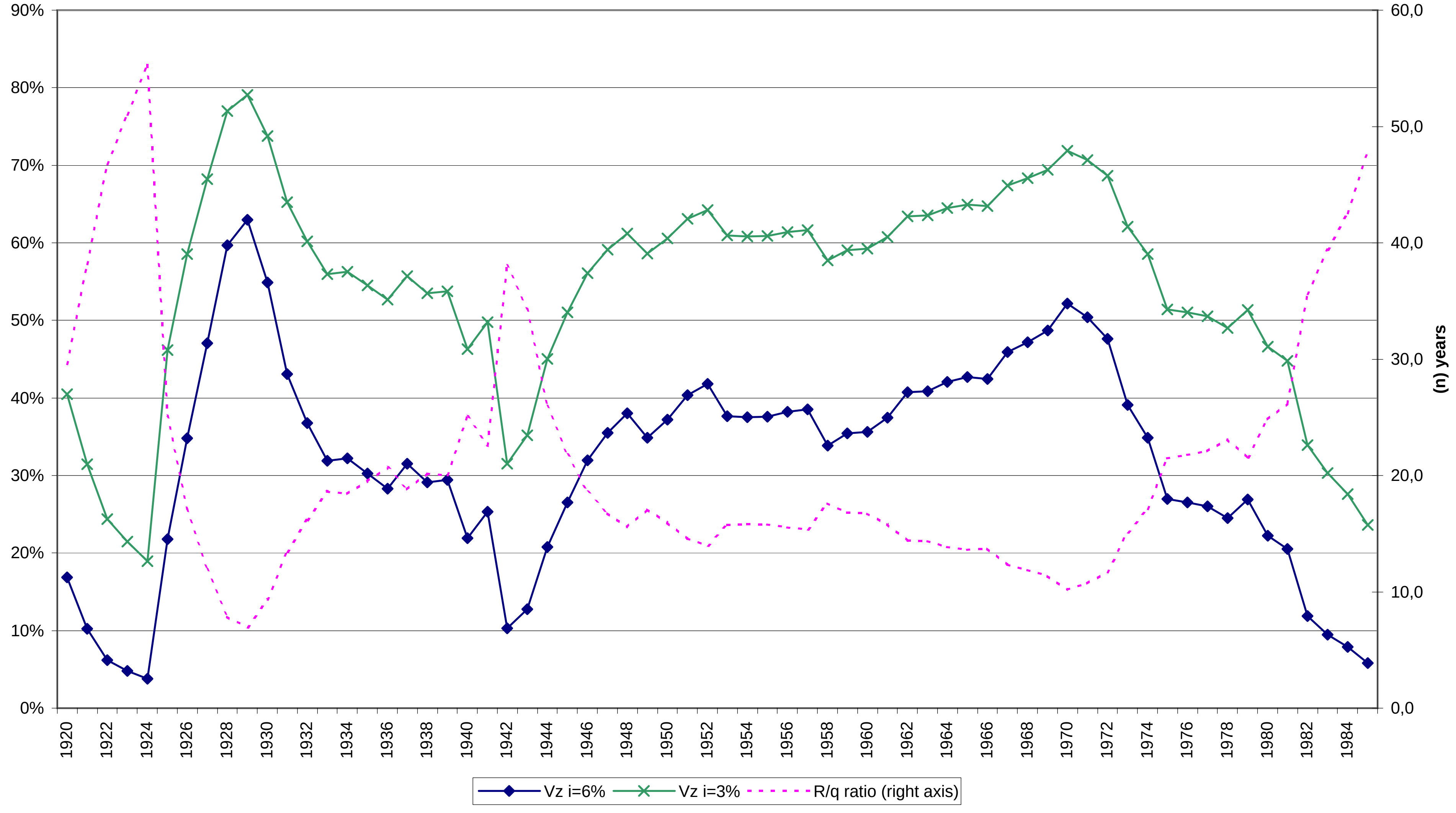


Figure 7: Mexico 1920-1985: Porportion of the net receipt that should be accounted as user cost (left axis)