On the Futility of the Resource-Rent Tax

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Abstract. Resource rent is a particularly attractive base for tax because it is unearned, being a "free gift" of nature, and because, in theory, taxing does not induce distortions since the rent is paid over and above what is necessary to induce a decision. The tax base is a residual, revenue net of cost including full capital cost. Non-marked capital, such as organization and proprietary processing methods, however, is also vital in extraction and is confounded with the resource in producing value. The twin objectives of capturing rent and avoiding distortion are found to be inachievable and other approaches to taxation are suggested.

Key words: resource-rent tax, capital value, non-marketed capital, intangible capital

Introduction

A resource-rent tax has two aims. First, its main purpose is to collect all (or at least a high proportion) of the rent attributable to non-renewable resources such as hydrocarbons or hard-rock minerals. Second, because it targets rent, which is defined to be an income that is not necessary to support a given level of activity, an intent is to cause no distortion of any decision concerning the extraction of the resource. The justification for the tax is to gain "for the people" a resource value to which they are considered to have a right as a part of their patrimony. It is considered to substitute for other forms of tax that gain less of the rent and induce significant distortions.[1]

Resource rent is thus a particularly attractive base for tax because it is unearned, being a "free gift" of nature, and because, in theory, taxing does not induce distortions since the rent is paid over and above what is necessary to induce a decision. The avoidance of distortion makes the notion of fairness more unequivocal by entwining it with the idea of efficiency.

In a resource-rent tax, any legitimate cost incurred by the firm extracting the resource is deducted from the tax base. Deductions include the "normal" or required return to invested capital as well as the depreciation of the initial price of the capital through time. Interest plus depreciation are applied to the undepreciated balance of the capital stock until it is fully depreciated. What

[1] Forms of tax include (a) a royalty (a percentage of gross value produced), (b) a corporate income tax, (c) mining taxes that are similar to income taxes but have special provisions (mainly special types of deduction), (d) various types of property tax, and (e) lease fees or auctions (that in principle could gain the full net rent as a capitalized charge but in practice can depart significantly from the ideal). See Cairns (1982).

remains is a residual, revenue net of cost including full capital cost. This formulation as a residual recognizes that, even though some properties are bought and sold in markets, information is not perfect and it is not possible for the government to obtain an accurate measure of the value of the resource. The residual is deemed to be rent and is taxed at a rate τ that is usually viewed as equalling or approaching 100%.

For example, for a petroleum reserve of size R_t producing at time *t* and net price of output $(p-c)_t$, Adelman's (1990) rule is that the net present value of a producing mineral reserve (once the firm has invested in developing the reserve) is *approximated* by $\tilde{V}_t \approx \frac{1}{2}(p-c)_t R_t$. If the reserve is not priced in a market (because, say, it is developed by the firm that discovered it), then the present value of the extractive operation (invested capital plus resource rent) just after it is developed at time 0 and at cost I_0 is sometimes considered to be $J_0 \triangleq V_0 + I_0$. The target of the resource rent tax at $t = 0$ is the true value V_0. Interest (r) plus depreciation (δ) are allowed on the undepreciated capital balance I_t in periods $t > 0$ and, given an output q_t , a tax of $\tau[(p-c)_t q_t - (r+\delta)J_t]$ is assessed.

Since the reserve is not usually sold or auctioned and in any case since a sale or auction is considered not to produce an accurate valuation, the reserve can be called *non-marketed capital* and not to have a market price. Non-marked capital of other sorts is also vital in extraction. If, for example, an exploration firm discovers a reserve and sells the discovery to another firm that is more efficient at exploiting the reserve, there is an observed transaction for the reserve, so that it becomes marketed capital with a market price. However, there is also a *rent of composition* (Alchian 2008), namely, the value of the acquiring firm's right to the project, or the value of the project net of the cash costs including the cost of the transaction (leaving a reduced residual rent

to the firm). Sources of the greater efficiency are other non-marketed assets held by the acquiring firm including, among other things, organization and proprietary processing methods. If, on the other hand, the more efficient firm discovers the reserve, the reserve is developed by that firm. Again, the values of at least two non-marketed assets, the reserve and the firm's organizational capital, are confounded in the residual.

The importance of organization and other non-marketed capital owned by the firm is suggested by the fact that the government does not avail itself of the option to set up a government-owned firm.[2] The value of the resource is endogenous to the distribution of skills among the various institutions in the economy.

The capitalized rent, V_0 , however, is the aggregate, realizable value that notionally at least accrue to all forms of non-marketed capital, not just the resource itself: the tax base includes the aggregate of such flows as "Hotelling" or scarcity rent, "Ricardian" or differential rent, rents to proprietary processing methods, rents to organization, rents to entrepreneurship, rents to "effort", monopoly rent, etc. Non-marketed capital is an omelet that cannot be unscrambled to reveal a contribution to be attributed to the resource alone. Many of the sources are qualitative and without natural units of measurement.

[2] If it does set up a government-owned firm, the government typically extracts with much less efficiency. It may be aware of this fact but still wish to encourage employment or to achieve some other objective, thereby dissipating some of the residual that a well organized firm would produce. If such objectives are pursued with the resource-rent tax, then presumably the additional costs are part of the deductions made by the firm.

Consequently, it is not feasible to define, let alone to target, the rent to be attributed to the resource, which is the object of the resource-rent tax. The net present value V_0 is the aggregate of the capitalized contributions of all sources of rent.

Even if there is no distortion, so that the pattern of production and net receipts (including resource-rent-tax receipts) from extraction over the reserve's life are the same as when there is no tax, the base for the resource-rent tax is not limited to resource rent. The "fairness" justification for levying a high rate of tax, which is to return the value of an asset to its "rightful" owners, "the people", is undone: the tax captures other types of rent having other "rightful" owners. The rationale of the tax is thus little different from other forms of taxation.

The question of distortion remains: a resource rent tax could be more efficient in levying a given total tax take from a private corporation.

Intangible and Non-Marketed Capital

Typically, capital theory and investment theory have considered the value of a project or firm as being a function of a single type of capital, or of capital that can be reduced to a scalar. The resource-rent tax is a policy that recognizes explicitly that non-marketed capital in the form of a given reserve, as well as marketed capital, should be incorporated into a firm's capital stock. Since the two have different analytical properties, they cannot be reduced to a single asset for analytical purposes.

In capital theory, non-marketed assets are sometimes identified as being intangible. In recent years, far-reaching questions in capital theory have been raised about intangible capital. Hall (2001) argues that it is empirically important and Corrado, Hulten and Sichel (2009) that it is a major contributor to economic growth. Even though many intangible assets are not priced in a

market, the example of a mineral reserve that is developed directly by the discovering firm suggests that intangible and non-marketed capital are not identical, Subsuming intangible capital into *non-marketed* capital, Abraham (2005: 10-15) notes that the latter is increasingly important in modern economies.

The theory of comprehensive national accounting (e.g. Weitzman 1976, 2003), a generalization of the ideas of "green" accounting, stresses that, in addition to the traditional produced means of production, an economy's capital encompasses assets that do not have market prices. Their contribution emerges after the investment decision. Many environmental resources are tangible capital assets that do not have prices. While non-marketed assets do not have market prices, they are essential components of a firm or project's capital. Among the practical issues for analysis that are discussed in a volume edited by Corrado, Haltiwanger and Sichel (2005) are the lack of arm's-length valuations, inter-relatedness of assets, the strength of theoretic and empirical assumptions, and the estimation of deterioration and decay.

All of these have implications for the analysis of a simple resource-rent tax, which is designed to capture resource rent from a producing mineral property when there are a well-defined price of marketed capital and a well-defined net present value.

In the present treatment the view of a project is consonant with the irreversible investment of capital of multiple types. The simplest case, of several inputs at a single point in time, is studied. Capital is defined in terms of realizations of cash flows over time. A surplus that accrues over time can be capitalized. The source is viewed as a component of the capital of the project.

Conceptually, rent can be uncoupled from tangible assets by viewing a source of rent as a form of non-marketed capital. Non-marketed capital includes organization, entrepreneurship,

reputation, some tangible environmental goods without property rights, etc. Entry barriers – copyrights, tariff walls, brands or trademarks, etc. – are the bases for monopoly rent. These are qualities that Dixit and Pindyck (1994:9) argue underlie an investment opportunity. Firms invest to enhance and to maintain their entry barriers. Entry barriers have all of the analytic properties of assets. Some types of intangible capital are not mediated in markets because they are qualitative and do not have natural units of measurement, such as organization (Lev and Radhakrishnan 2006: 74). A stylized fact about non-marketed capital is that it is not tangible and has no units.

A typical mining or petroleum project has many of these attributes. The only way to set a tax is through observation and some sort of accounting. In this exercise we follow Cairns (2013), who outlines the possibilities for accounting when capital variables are not all observable through time.

3. Non-Marketed Capital as a Residual

Let the vector of marketed capital goods at time $t \geq 0$ be represented by the m_t-vector M_t and the vector of non-marketed capital goods by the n_t-vector N_t. The *project* consists of the vector of capital stocks, (M_t, N_t). Let the length of the project's life be represented by $T \leq \infty$ and the real interest rate in period *t* by r_t. Suppose that a resource-allocation mechanism (RAM) is in effect for the project (Dasgupta and Mäler 2001) and leads to a realization of variable profit or net cash flow in period *t* of f_t. Variable profit may arise from the sales of one or more products or services (e.g., various types of petroleum products from the same reserve or various metals from the same mine or technical advice to customers). Products and services may or may not be bundled; non-linear prices may prevail. At time $t < T$, the realization of the project is the vector

of its future net cash flows, $(f_{t+1},...,f_T)$. The *value* of the project is the present value of these net cash flows. At $t = 0$,

$$V_0 = \sum_{t=1}^{T} \frac{f_t}{\prod_{s=1}^{t}(1+r_s)} \ . \qquad (1)$$

All the capital goods (M_0, N_0) in concert – not severally – produce the value, V_0. Like the atoms in a chemical compound, marketed and non-marketed capital are transformed and coalesced into the project. Aggregation of the marketed capital is in a common unit, the numeraire, and has an observable value I_0. So long as a particular marketed-capital good remains with its project, in many cases until it is scrapped, its contribution comes not solely on its own account but as a result of complementarity with other capital goods, including the non-marketed goods N_0.

The vital point is that the project's income is not composed of or allocated among distinct contributions from individual assets but from the composition of all of them. The price of marketed assets is observed and an aggregate of marketed capital is possible in monetary terms. Future flows can be assumed to be known or projected. However, the non-marketed capital is composed of disparate residuals that are confounded.

Since the contributions of a non-marketed asset depend on complementarity with the other assets, both marketed and non-marketed, they are specific to the project (cf. Oliner 1996: 69). Their values cannot be accurately ascertained by comparison with other projects. If units of an intangible capital good can be devised and it has a price (e.g., a licenced patent or purchased software) then it can be classed among the marketed capital goods. Thus, there is a subtle distinction between intangible and non-marketed capital. The value of a non-marketed asset is not directly observed. Since there is no unit and no aggregate, a marginal value is not defined.

The non-marketed capital is a bundle of attributes of the extractive firm that has a composite value equal to the discounted net cash flow or variable profit. That value is a residual, $J_0 \equiv V_0 - I_0$. The non-marketed assets have incremental values, but in general, because of complementarity, the incremental values do not sum to J_0. Even under certainty, the contributions of the non-marketed assets are confounded. Accordingly, some econometric studies interact the influences of some of the marketed, tangible items.

The total, residual, present value net of the cost of marketed capital, is defined by Hall (2000, 2001) and the World Bank (2011) as *intangible* capital. An uncertainty principle applies: "Hall's residual contains a diverse collection of factors that we will never fully understand" (Lamont 2000: 113). Comparable assets with market prices cannot be defined and used to reduce the residual to zero.

Dixit and Pindcyk's analysis implies that the investment *I* cannot be analyzed in isolation from the investment *J*. Total value of a producing project is $\sum_{t=1}^{T} \frac{f_t}{\prod_{t=1}^{T}(1+r_t)} = V_0 = I_0 + J_0$.

4. Taxation

If perfectly designed, the resource rent tax reduces the value of J_0 proportionally, capturing it by implementing a payment schedule (Baumol, Panzar and Willig 1982) v_t for the marketed assets over time such that $\sum_{t=1}^{T} \frac{v_t}{\prod_{t=1}^{T}(1+r_t)} = I_0$ and subtracting it from the variable profits at time *t*, and then applying the tax rate τ to obtain the tax. If the tax remains constant and all of the nonmarketed assets are given as of date zero, one might reason that the tax would not affect the timing of investment or any other decision.

More generally, under both certainty and uncertainty, a project -- resource or otherwise -- is optimally brought on stream when its net present value is rising at the rate of interest (Cairns and Davis 2007, Davis and Cairns 2012). This condition is a forward-looking smooth-pasting condition, with net present value (NPV) expressed as an expected value before the decision to invest (cf. Dixit and Pindyck 1994: 108). Taxes affect decisions of a producing firm. By changing the anticipated pattern of cash flows f_t from the project, and in general taxes also affect the calculations of NPV, including the time at which it is rising at *r*. Conditions before investment, then, influence conditions after. An important source of deadweight loss from a tax is the change in the timing of investment.

If perfectly designed, the resource rent tax reduces NPV proportionally and may not affect timing. However, an important non-marketed investment in nonrenewable-resource industry is exploration. If exploration expenditures are not adequately recognized, timing and indeed the choice of level of exploration (number of wells drilled, for example) are affected (Smith 2014). Moreover, because of important knowledge spill-overs from exploration to other prospects of the same firm and to other firms, it is not possible to make an adequate provision for exploration. Timing of development investment may also be affected.

In practice, such expenditures as exploration and development have been recognized for tax purposes through depletion allowances. Depletion allowances may implicitly recognize the importance of not taxing other forms of non-marketed investment, most notably organization and "effort". It is arguable that only ad-hoc measures are possible.

There are other assets that may be endogenous and non-marketed. These can be subsumed under "effort" and include dealings with labour during the life of the project, dealings with suppliers,

choice of cut-off grade (Cairns and Shinkuma 2005), managers' willingness to stay after hours. There are myriad such forms of "effort". Laffont and Tirole's (1993) model becomes increasingly complex, quickly becoming intractable, with a single source of "quality" of the firm and a single dimension of "effort". The case of a mine is even more complicated (cf. Ing 2018).

5. The Confounded Resource-Rent Tax

Following Laffont and Tirole (1993), let the observable form of cost be unit, accounting cost at any time and be a function of unobservable effort (e), management capacity (M) and quality of ore (G). Suppose that conditions are stationary, including price and that capital cost F(K) is incurred at time 0. This is false dynamics; the decisions are stationary. The government imposes a tax τ, $0 \leq \tau < 1$, on revenues net of cost and of a depreciation allowance δ with present value equal to F(K) to allow the firm to recover its investment without tax. There is a homogeneous resource with initial reserve R.

In addition, there are exploration expenditures G(B), and the probability of a discovery is $\pi(B)$. The cost of effort to the firm is given by $\psi(e)$, increasing and strictly convex. Therefore, the firm's decision is based on the following net present value (rent):

$$V = - G(B) - \pi(B)\{F(K) + [(1 - \tau)(pq - c(e,M,G)q) + \delta\tau - \psi(e)][1 - \exp(-rT)]/r\}$$

$$= - G(B) - \pi(B)\{F(K)(1 - \tau) + [(1 - \tau)(p - c(e,M,G))K - \psi(e)][1 - \exp(-rR/K)]/r\}$$

$$= - G(B) - \pi(B)\{F(K)(1 - \tau) +[(1 - \tau)(p - c(e,M,G))K - \psi(e)]f(K)\}.$$

Notice that the exploration expense is not included in depreciation and that the cost of effort is not credited in the tax calculation. These are two sources of distortion by the resource rent tax. There is a deadweight loss.

Consider the effect of effort.

$\partial V/\partial e = f[-(1 - \tau)\partial c/\partial e - \psi'] = 0.$

There is a distortion: $\psi' = -(1 - \tau)\partial c/\partial e$, so that effort is less in response to the tax. Also, exploration is distorted away from the zero-tax situation. The resource-rent tax is not neutral.

Moreover, the resource-rent tax is not a tax on the resource rent. We can define the marginal effect of the quality of the ore on cost, $-Kf\partial c(e,M,G)/\partial G$; this is the marginal rent (defined, recall, as a present value). But this value is not the resource rent. It is confounded with effort and managerial rent. None of these is observed, and indeed, managerial rent (the return on managerial capital) is not transacted. To define the resource rent, one would have to define the difference, for a given level of managerial capital, between the present values for two discrete changes in grade and so on.

The quality of ore is such that the total rent is zero when

$V = -G(B) - \pi(B)\{F(K)(1 - \tau) + [(1 - \tau)(p - c(e,M,G))K - \psi(e)]f(K)\} = 0$

and when

$\partial V/\partial e = f[-(1 - \tau)\partial c/\partial e - \psi'] = 0.$

For regular functions, these equations define a curve in the space (e,M,G); none of e, M or G is observed. For each point on the curve, there is a value of K and of e. If the true value of M could be observed, there would be a value of G.

There is no observable way to define the rent that can be attributed to the resource.

If the deadweight loss is a convex function of the tax τ, then there is a trade-off between the effects of this form of tax and other forms, such as a tax per unit of ore, a lease tax and a traditional income tax; a choice of each with positive rates would minimize the deadweight loss for a given revenue (present value) for the government.

6. Discussion

Many assets are sunk in a mining enterprise, including several forms of non-marketed capital. If none of the non-marketed capital is elastic to the tax, there is no inefficiency. Even so, the justifications of fairness and efficiency for taxing the residual fails because it incorporates many forms of rent, not just resource rent.

If there are elastic factors, the resource rent tax causes distortion, contrary to the second of its aims. These factors can be subsumed under "effort" and include exploration, high grading, bargaining with unions, level of recovery of secondary minerals, etc.. Reduction of exploration effort may imply that a reserve is not discovered. Extracting rent to organization or effort may mean that an efficient firm declines to participate. Yet a government may have to pre-announce a tax measure that is intended to apply to several different properties and even minerals.

Deadweight losses tend to be convex functions of the rate of tax. In the case of a resource-rent tax, the rate is high (in theory 100%) and is applied to a base that is narrower than a royalty ($p_t q_t$) or a corporate income tax, which does not have a deduction for the normal return to capital. Since its target is a residual that is made up of all sources or rent and not just resource rent, a resource-rent tax may entail large deadweight losses and not be efficient at all.

Presumably the government has turned to the firm instead of using a government-owned corporation because the firm can do the job better than a government corporation. The

government does, however, wish to obtain a revenue from the natural assets in its control. In practice, typically, there are several forms of tax such as a royalty on total gross revenues at a limited rate, a corporate income tax (sometimes with special provisions such as a depletion allowance), and a special mining tax that targets a net amount that allows for more deductions. Any form of tax impinges on decisions by the firm and the deadweight cost of the distortions increases is a convex function of the tax rate. Helliwell (1982) suggests that the plurality of taxes that are observed in some jurisdictions, such as Canada, may possibly have the desirable characteristic (intended or not) of lessening the total deadweight losses.

7. Conclusion

The justification for a resource-rent tax as being a means of capturing the value of and only the value of scarce natural resources for the public rather than private investors does not hold in reality because there are many sources of non-marketed rent that forms a residual of total present value net of marketed capital. Some of these rents, such as management and production methods, are essential to production. Indeed, the famous dictum of the 1970s that "resources are not; they become" holds that a reserve does not become useful until it is made useful by the demands of consumers, by substitution for other resources or by decreases in cost of production. Much of the rent, perhaps a very large part, cannot be considered to be attributable to the resource itself.

Indeed, if any of the sources of rent is elastic to the resource-rent tax (such as effort by managers and employees), the observed net present value of the operation is distorted by the tax. Decisions about exploration can clearly be distorted and cause deadweight losses.

In practice, such expenditures as exploration and development have been recognized for tax purposes through depletion allowances. Depletion allowances may implicitly recognize the

importance of not taxing other forms of non-marketed investment, most notably organization and "effort". It is arguable that only ad-hoc measures are possible.

The findings of this paper have more general implications for the practice of green accounting. The aim of green accounting is to find accounting values for non-marketed natural assets. Much of the theory behind green accounting developed with its original example being a mineral deposit producing a rent. If natural assets are used in conjunction with other non-marketed capital in a project, as is always the case, there is no unique value for the natural asset. Instead, it is confounded with the values of other non-marketed assets, natural and other.

References

Abraham, Katherine G. (2005), "What We Don't Know Could Hurt Us: Some Reflections on the Measurement of Economic Activity," *Journal of Economic Perspectives* 19, 3, 3-18.

Adelman, Morris A. (1990), "Mineral Depletion with Special Reference to Petroleum"', *Review of Economics and Statistics* 72, 1: 1-10.

Alchian, Arman A. (2008), "Rent", *The New Palgrave Dictionary of Economics*, Second Edition, Eds. Steven N. Durlauf and Lawrence E. Blume, Palgrave Macmillan.

Brandt, Nicola, Paul Schreyer and Vera Zipperer (2015), "Productivity Measurement with Natural Capital", mimeo, OECD, Paris, presented to the annual meeting of the Society for Economic Measurement, Paris, July.

Brock, William A., Michael Rothschild and Joseph E. Stiglitz (1989), "Stochastic Capital Theory", in *Joan Robinson and Modern Economic Theory*, ed. George R. Feiwel, New York: New York University Press, 591-622.

Cairns, Robert D. (1982), "Extractive Resource Taxation in Canada, in *Tax Policy Options in the 1980s*, W.R. Thirsk and J. Whalley (eds.):255-288.

Cairns, Robert D. (2013), "The Fundamental Problem of Accounting", *Canadian Journal of Economics* 46, 2: 634-655.

Cairns, Robert D. and Graham A. Davis (2007)", Strike when the Force is With You: Optimal Stopping and Resource Equilibria", *American Journal of Agricultural Economics* 89, 2, 461-472.

Corrado, C., J. Haltiwanger and D. Sichel, eds. (2005), *Measuring Capital in the New Economy*, Chicago: University of Chicago Press.

Corrado, Carol, Charles Hulten and Daniel Sichel (2009), "Intangible Capital and U.S. Economic Growth" *Review of Income and Wealth* 55, 3: 661-685.

Dasgupta, Partha and Karl-Goran Mäler (2000), "Net National Product, Wealth and Social Well-Being", *Environment and Development Economics* 5, 1&2: 69-93.

Davis, Graham A. and Robert D. Cairns (2012), "Good Timing: The Economics of Optimal Stopping", *Journal of Economic Dynamics and Control* 36, 1: 255 - 265.

Diewert, W. Erwin (2006), "The Measurement of Income", CAER Working Paper 2006/11, Faculty of Commerce and Economics, University of New South Wales.

Diewert, W. Erwin (2009), "The Aggregation of Capital over Vintages in a Model of Embodied Technical Progress", *Journal of Productivity Analysis* 32: 1-19.

Dixit, Avinash K. and Robert S. Pindyck (1994), *Investment under Uncertainty*, Princeton University Press.

Doms, Mark E. (1996), "Estimating Capital Efficiency Schedules within Production Functions", *Economic Inquiry* XXXIV: 78-92.

Hall, Robert E. (2000), "E-Capital: The Link between the Stock Market and the Labor Market in the 1990s", *Brookings Papers on Economic Activity* 2: 73-102.

Hall, Robert E. (2001), "The Stock Market and Capital Accumulation", *American Economic Review* 91, 5: 1185-1202.

Helliwell, John F. (1982), "Comment" on Cairns (1982), in *Tax Policy Options in the 1980s*, W.R. Thirsk and J. Whalley eds., Canadian Tax Foundation

Ing, Julie (2018), "Adverse Selection, Commitment and Exhaustible Resource Taxation", working paper, Centre de Recherche en Economie et Management, University of Rennes.

Jorgenson, Dale W. (1996), "Empirical Studies of Depreciation", *Economic Inquiry* XXXIV: 24-42.

Lamont, Owen A. (2000), "Discussion" of Hall (2000).

Lev, Baruch and Suresh Radhakrishnan (2005), "The Valuation of Organization Capital", in Corrado, Carol, John Haltiwanger and Daniel Sichel, eds., *Measuring Capital in the New Economy*, Studies in Income and Wealth vol 65, University of Chicago Press, Chicago: 73 - 99

Oliner, Stephen D. (1996),"New Evidence on the Retirement and Depreciation of Machine Tools", *Economic Inquiry* XXXIV: 57-77.

Smith, James L. (2014), "A Parsimonious Model of Tax Avoidance and Distortions in Petroleum Exploration and Development," *Energy Economics*, 43, 140-157.

Solow, Robert M. (1957), "Technical Change and the Aggregate Production Function", *Review of Economics and Statistics*

Weitzman, Martin L. (1976), "On the Welfare Significance of National Product in a Dynamic Economy"', *Quarterly Journal of Economics* 90: 156-162.

Weitzman, M. (2003), *Income, Wealth and the Maximum Principle*, Cambridge, MA: Harvard University Press.

World Bank (2011), *The Changing Wealth of Nations: Measuring Sustainable Development for the New Millennium*, Washington DC.