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Myopia, Emmetropia or Hypometropia? Competitive Markets and Intertemporal Efficiency in the Utilization of Exhaustible Resources

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MYOPIA, EMMETROPIA OR HYPERMETROPIA? COMPETITIVE MARKETS AND INTERTEMPORAL EFFICIENCY IN THE UTILIZATION OF EXHAUSTIBLE RESOURCES

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FORWARD

Stephen P. Dresch is chairman of the Institute for Demographic and Economic Studies in New Haven, Connecticut, and currently a IIASA research scholar in the program on Economic Structural Change. While best known for his research in the economics of human resources, in this particular paper he focuses on an important concern for the theory of resource exhaustion and the discipline of mineral economics. Specifically, he assesses the widespread concern that the markets for minerals and other exhaustible resources may be myopic in the sense that they do not save enough of these limited resources for future use.

In association with the Economic Structural Change Program, led by Wilhelm Krelle, the Mineral Trade and Markets Project is circulating this study as a working paper in the hope of stimulating interest in the topic in general and specific comments and suggestions on the paper in particular.

John E. Tilton
Research Leader
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PREFACE AND ACKNOWLEDGEMENTS

Over a period of years my attention has been repeatedly drawn to the concept of ***myopia*** as it is employed in the literatures of economics and other social and policy sciences. While ostensibly a "scientific" concept, myopia as conventionally utilized almost invariably is associated with an undertone of religiosity, paternalism and exhortation. Whatever the putatively scientific observer finds objectionable in the behavior and performance of individuals and institutions is characterized as "myopic," attributable only to the failure of the involved parties to adequately recognize and take into account the future consequences of current actions. This paper represents a first attempt to provide a more scientific basis for the concept of myopia, and in particular to emphasize the possibility of the converse form of "misperception" of the future, ***hypermetropia***, conjoining the conceptual elaboration with empirical tests in the case of markets for "exhaustible resources."

Preparation of this paper was stimulated by conversations with Christian Lager, Ryoichi Nishimiya, Mitsuo Saito, Ernõ Zalai and Wolfgang Schöpp of IIASA. Eduard Löser of the IIASA library disabused me of my naïve belief in the originality of the terminological constructs, ***hypermetropia*** and ***emmetropia***. The current version has benefited significantly from the constructive criticisms of an earlier draft of Ruthann Moomy, Anatoli Smyshlyaev, John Tilton and, especially, Wilhelm Krelle, also of IIASA. I alone remain responsible for errors and for duplication of what may well be a prior literature with which I am inadequately familiar.

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MYOPIA, EMMETROPIA OR HYPERMETROPIA? COMPETITIVE MARKETS AND INTERTEMPORAL EFFICIENCY IN THE UTILIZATION OF EXHAUSTIBLE RESOURCES

Stephen P. Dresch

1. Pseudoscientism and the Concept of Myopia

Myopia,[1] i.e., systematic "undervaluation"[2] of future consumption possibilities by comparison to consumption in the present, is frequently alleged to vitiate the efficiency of market-determined intertemporal allocations of resources. While *emmetropia*, the "correct" relative

[1]Borrowing from the terminology of optics and opthalmology, economics and related social sciences have made extensive use of the concept of *myopia* (shortsightedness), a distortion of vision in which the image falls behind the retina of the eye (producing clear perception only of objects relatively close to the observer). Unfortunately, economics and other social sciences have not made comparable use of the converse form of *ametropia* (distortion of vision, in contrast to *emmetropia*, normal vision in which the image falls upon the retina, providing clear perception of both near and distant objects), *hypermetropia* (farsightedness), a distortion in which the image falls in front of the retina (producing relatively clear perception of objects very far from the observer). The only reference in the economics literature to hypermetropia (of which the present author is aware) is that of John F. O'Connell, "Wages and Job Change: Myopia or Hypermetropia," *Journal of Economics and Business* (Fall 1980). The foregoing optical/opthalmological concepts and terminology are summarized under the topic of "Vision," *Encyclopaedia Britannica*, vol. 23, p. 70 (Chicago: Encyclopaedia Britannica Press, 1973).

[2]In this introduction the terms "undervaluation," "correct valuation" and "overvaluation," all referring to the relative valuation of future by comparison to present consumption, are used without formal definition. Such definitions will be provided in the following section.

valuation of consumption possibilities at different points in time, is taken as the norm or standard, myopia is considered to be pervasive, possibly even endemic. Thus, for example, conservationists, environmentalists and advocates of zero-population-growth conjoin the concepts of myopia and externalities to explain the failure of contemporary societies to control the growth of population, to reduce the excessively rapid rate of exploitation of nonrenewable resources, and to anticipate the adverse future environmental consequences of current economic activities.[3]

Despite the prevalence with which recourse is made to alleged myopia as an explanation for (similarly alleged) market failure, it is notable that empirical tests are rarely performed to confirm the existence and influence of myopia.[4] The observed phenomena, e.g., "excessively rapid" population growth, resource "exhaustion," environmental "degradation," etc., *ad infinitum*, are apparently conceived as selfevident, both normatively and with reference to their underlying sources. Also, surprisingly, despite the frequency with which myopia is alleged, the literature is virtually devoid of the suggestion that markets might fail due to the converse distortion of perception, ***hypermetropia***, the "excessive" valuation of future relative to current consumption possibilities. Certainly, if one can be scientifically defined, the other should also be subject to scientific definition, and on theoretical grounds one should be

[3]For a review (and pointed critique) of these claims, see Julian Simon, ***The Ultimate Resource*** (New York: Oxford University Press, 1981).

[4]Presupposing an analysis such as that developed here, Simon, *ibid.*, emphasizes the observation of declining relative resource prices as refuting claims of excessively rapid resource exhaustion.

as subject to operational observation as the other. In short, if myopia is to be convincingly offered as an explanation for a market failure of any specific type, a meaningful empirical test must be offered, and that test must permit the finding either of myopia, of emmetropia or of hypermetropia. This paper develops and applies such a test with reference to the market-determined, intertemporal utilization of exhaustible resources.

2. Emmetropic Resource Price Trajectories with Certainty and Perfect Capital Markets

The focus of interest here is the rate of utilization over time of an "exhaustible resource." However, it is useful to define the problem as generally, and realistically, as possible. Thus, an exhaustible resource, for present purposes, can be conceived as follows: At a point in time there exists a "known resource stock," denoted here, for short-hand purposes, as a "known reserve."[5] Subject to (modifiable) "extraction" capacities,[6] this known reserve can be extracted and "used" (embodied in final goods and services) at any point in time.[7] While current use cannot

[5] In the resource-economics literature the concept of a resource reserve is commonly restricted to those known sources the exploitation of which is economical, i.e., for which price exceeds extraction costs, given current factor prices and extraction technology. The "resource base" then consists of reserves plus resource endowments which it is not (currently) economical to exploit. Here the term is used essentially as a synonym for resource base in this broad sense.

[6] For present purposes it is convenient to assume that the known reserve is homogeneous and can be extracted at constant costs (constant both at a point in time and over time). However, this restrictive assumption is in fact unnecessary, as will be discussed further. Thus, extraction costs can either rise with cumulative extraction (due to a deterioration in the quality of remaining reserves, i.e., to "resource exhaustion") or can rise/fall with time *per se* (due to secular changes in factor prices or to changes in extraction technology). None of these possible extraction-cost developments requires a significant modification of the essential conclusions of this analysis.

[7] As just suggested, the terms "use," and also "end use" and "final use" are employed here interchangeably to refer to embodiment of the resource in final goods and services (consumption, investment, etc.) ***other than inventories of the resource itself.***

exceed the known reserve, cumulative uses over the infinite future can exceed the reserve as a result of (a) the discovery of previously unknown reserves, (b) changes in extraction and related technologies (increasing the efficiency of physical extraction, defined as the ratio of usable resource extracted relative to the total quantity extracted) and (c) recycling of previously used reserves.

Two distinct classes of demand for the currently-known reserve can be identified. First, there is a "flow demand" for current use. Current and future flow, or "end-use," demands for the resource are functions of (a) aggregate levels of economic activity (changing over time as a result of increases in population-*cum*-laborforce and in the capital stock, as well as general technological progress), (b) the composition of final demand (also subject to change over time, as a result, e.g., of changes in relative prices, in savings rates and in consumer preferences) and (c) technological developments in resource-using sectors and activities. *Ceteris paribus*, the quantity of the resource demanded for current use at any point in time is assumed to adjust so as to maintain equality between the then-current price and the marginal productivity of resource use.

The second category of demand is a "stock (or inventory) demand" for known reserves to be carried into the future. It can be assumed, provisionally, that quantities of the resource fulfilling the stock demand are held in raw, unextracted form *in situ*, at no cost other than deferral of final use (reflected in interest costs, either interest paid or interest income foregone), i.e., that there are no costs of storage or losses to deterioration.[8] This stock or inventory demand sets an upper bound on

[8]In fact, this assumption is unnecessarily restrictive. Even in those instances in which the

cumulative future end uses. Thus, the stock demand must be greater than or equal to the sum of all future end uses less (a) future reserve discoveries, (b) augmentations of the extracted resource due to advances in extraction technology and (c) future supplies to final use accounted for by recycling.

In a regime of perfectly competitive markets, the stock demand is determined subject to the requirement of profit maximization of all participants in all markets (and market segments). A single price confronts all purchasers, whether the motive is end-use or stock demand. With perfect capital markets investors in reserve stocks can borrow in order to acquire reserves at the market interest rate. Under these circumstances, investors will acquire stocks (for future sale) as long as the anticipated rate of change of price is at least equal to the interest rate.[9] Were price to increase at a rate greater than the rate of interest, it would be profitable for investors to acquire additional stock reserves, the (economic) profits on which would equal the difference between the rate of change of price and the interest rate.[10] Under these circumstances, increases in demand for reserve stocks would drive up the current price, reducing current flows of the resource to end use, while greater future resource availabilities would reduce the future resource price, a process which would continue until the rate of resource price change was driven to equality with the interest rate. Conversely, a rate of change in the

stock demand is satisfied by resources in an extracted form or is subject to storage costs and deterioration, the essential conclusions of this analysis are unaltered, as will be explained.

[9]This is simply the well-known "Hotelling rule." See H. Hotelling, "The Economics of Exhaustible Resources," *Journal of Political Economy* (1931).

[10]Profit here is used in its economic sense, referring to a surplus over costs, where costs include a return to capital at the market rate of interest.

resource price less than the interest rate would imply losses for investors in reserve stocks, leading to reductions in reserve stocks which would reduce the current price, while lesser future resource availability would raise the future price, resulting, again, in a process which would continue until the rate of resource price change was brought into equality with the interest rate.[11] Thus, *in equilibrium*, the price of the resource must rise over time at the rate of interest.[12]

This perfectly competitive market equilibrium, determining the allocation of known reserves between end-use and reserve stocks, or, equivalently, between current and future end-use, can also be demonstrated to be socially optimal. Specifically, the change of the resource price over time is a measure of the higher marginal productivity of the resource in the future than in the present, while the interest rate is equal to (a) the rate of return to physical capital and (b) the marginal rate of time preference (the rate at which individuals are willing to exchange present for future consumption). If the rate of change of the resource price (marginal productivity of the resource) is greater than the rate of return to capital, then total output, income and consumption (present and/or future) can be increased if reserve stocks of the

[11]Strictly speaking, these market-equilibrating developments should be conceived as achieved *via* a process of Walrasian *tantonnement* or Edgeworthian "recontracting," such that no transactions in fact occur at disequilibrium prices, since disequilibrium transactions may (through their effects on income distribution) alter the final equilibrium. The alternative solution to this problem is Marshall's assumption of the constant marginal utility of money (as reflected in his development of the pure theory of exchange, with reference to the "corn market"). See: Léon Walras, *Eléments d'économie politique pure (Théorie de la richesse sociale)* [1874-7], 5th edition (Paris and Lausanne, 1926); Francis Ysidro Edgeworth, *Mathematical Psychics* (1881); and Alfred Marshall, *Principles of Economics* [1890], 4th edition (London, 1898).

[12]Note that the focus of interest here is the *relationship* between prices at different points of time, not the *level* of prices at any point in time. Thus, this analysis says nothing about the level of prices *per se*.

resource are increased while investment in physical capital is correspondingly reduced, simply because the gain in future output associated with greater availability of the resource is greater than the loss of future output associated with the reduction in the capital stock. This will continue to be true until the rate of change of the resource price (or resource productivity) is equal to the interest rate and rate of return to capital. Conversely, a rate of change of the resource price less than the interest rate indicates that a gain in present/future welfare can be achieved if lesser reserve stocks of the resource are carried into the future, compensating for the reduced future availability of the resource by increases in investment in physical capital; the loss in future output due to the lesser availability of the resource will be more than offset by the gain in future output achieved through the larger capital stock, while the higher current rate of investment will be compensated by also higher current resource use.

3. Myopic/Hypermetropic Resource Price Trajectories with Uncertainty and Imperfect Capital Markets

With complete information and perfect certainty concerning all present and future prices, the foregoing perfectly-competitive, socially-optimal solution would be definitional. In the absence of certain knowledge of the future, however, reserve stock demands depend not on prior *knowledge* of future prices but on investors' *speculative expectations* concerning these. Moreover, if capital markets are imperfect, then it may not be possible to finance speculative investments in reserve stocks of a resource even if these investments are expected to be profitable at prevailing rates of interest (and returns to capital).[13] Only if capital markets permit the financing of speculative investments up to the point that the rate of resource price change *expected* by speculators is equal to the market interest rate and if speculative expectations of resource price change do not diverge systematically from the rate of resource price change which actually materializes will efficiency in intertemporal utilization of resources be achieved. The former requires perfect capital markets, while the latter requires speculative expectations which correctly anticipate future resource discoveries and changes in technology, composition of demand, etc.

At this point, uncertainty and imperfect capital markets permit the introduction of the possibility of myopia or hypermetropia, neither of which could otherwise be defined consistently. With uncertainty myopia and hypermetropia will be manifested in systematic discrepancies between expected and actual rates of resource price change. Thus, myopia must imply and be reflected in systematic underestimation of future prices, i.e., prices which actually materialize must be systematically higher than those anticipated in the past; equivalently, the rate of increase of resource prices must be greater than the rate of interest. And, conversely, hypermetropia must imply and be reflected in systematic overestimation of future prices, i.e., prices which materialize must systematically fall short of those expected; equivalently, the rate of resource price increase must fall consistently below the interest rate.

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[13] In effect, capital market imperfections may preclude equalization of the interest rate and (a) the individual's rate of time preference and (b) the rate of return to capital.

This uncertainty-based definition of myopia/hypermetropia, emphasizing systematic discrepancies between expected and actual future prices is equivalent to an imperfect-capital-market-based definition cast in terms of systematic discrepancies between internal rates of return to speculative inventory investments, on the one hand, and the market rate of interest, on the other. That is, *operationally* the consequences of systematic misperception of the future and the consequences of capital market imperfections are identical. Thus, myopia, the more likely manifestation of capital market imperfection, can be defined as a situation in which the realized internal rate of return to speculative stock reserve investments (equal to the rate of resource price change) systematically exceeds the market interest rate (implying a discrepancy between between rates of return to investment and savers' rates of time preference); conversely, hypermetropia is observed when the realized internal rate of return falls systematically short of the market interest rate.

To reiterate, ignoring reserve holding costs other than interest (either interest expense incurred or interest income foregone), the optimal intertemporal allocation to end use of an exhaustible resource will imply discounted future prices equal to the current price. Denoting price at time t by P_t, the interest rate by r, and the rate of growth of price (equal to the internal rate of return to investment in reserve stocks) by g [where $P_t = (1+g)^t P_0$],

$$P_t(1+r)^{-t} = P_0 \quad \text{or} \quad g = r \quad : \quad \textit{emmetropia}$$
$$P_t(1+r)^{-t} > P_0 \quad \text{or} \quad g > r \quad : \quad \textit{myopia}$$
$$P_t(1+r)^{-t} < P_0 \quad \text{or} \quad g < r \quad : \quad \textit{hypermetropia}$$

Thus, a simple test for the existence of myopia/hypermetropia is readily available.

4. Incorporating Noninterest Inventory Costs and Costs of Extraction and Processing

As noted at the outset, to simplify this analysis it was assumed that the reserve stocks of the resource were held over time only in a raw, unprocessed form *in situ*, and that there were no costs associated with holding the resource over time other than interest, i.e., that there were no "carrying costs," depreciation losses, etc. Because the empirical tests of the existence of myopia/hypermetropia presented in the next section, due to limitations of data, necessarily refer to resources in at least semiprocessed form, for which noninterest carrying costs cannot be assumed to be zero, it is important to demonstrate that the foregoing interest-rate/price-change relationships are essentially applicable in these cases as well.

When the resource is held in an extracted, processed form it is necessary to take into account the costs of these activities. Assuming zero noninterest carrying costs, the "emmetropic (Hotelling) rule" (rate of price change equal to rate of interest) sets an ***upper bound*** on the emmetropic rate of price change of the extracted, processed resource. Three specific cases can be distinguished, differing in terms of prospective changes over time in extraction/processing costs per unit of resource. First, if (implausibly) extraction and processing costs are expected to rise, purely as a function of time (i.e., not as a result of a deterioration in resource quality), at a rate greater than the rate of interest, an efficiently-functioning competitive market will extract and process the resource now, transferring only stocks of the extracted and processed resource to the future, with the consequence that the price of the processed resource will also rise over time (in the absence of myopia or hypermetropia) at the rate of interest.[14] Second, if extraction costs rise not with time *per se* but rather with cumulative output (as a result of resource exhaustion, i.e., deterioration in resource quality), then the economic rents received by resource owners (raw resource prices) at low cumulative output levels will reflect superior resource quality (lower extraction costs), with the price of the extracted resource rising over time at the rate of interest (as increases in extraction costs are offset by reductions in rents); equivalently stated, for "deposits" of any given quality, prices will rise over time at the rate of interest, price differentials between deposits of different quality will equal differences in extraction costs, and prices of the extracted resource will rise at the rate of interest, independently of the level of extraction costs. Third, only if processing costs are expected to rise over time at a rate less than the rate of interest will the price of the extracted, processed resource rise at a rate other (lower) than the rate of interest, in which case effectively no speculative inventories of the processed resource will be held; even in this case, however, the price of the raw resource will rise at the rate of interest, and the rate of change of the processed resource price

[14] This, obviously, requires current investment equal to extraction and processing costs. It might be argued that this could lead to a desired rate of investment greater than the current rate of savings. However, if this were the case, then the rate of interest would necessarily be driven upward, a process which would continue either until increases in savings and displacement of other investment were sufficient to permit complete, exhaustive extraction of the resource or until the rate of interest equalled the rate of change of resource extraction and processing costs, at which point there would be no incentive to extract and process the resource in the present rather than in the future.

will rise over time, asymptotically approaching the rate of interest as processing costs relative to rents asymptotically approach zero. Thus, regardless of the relationship of processing costs to time and cumulative resource output, in the absence of myopia/hypermetropia the rate of change of price of the resource (in extracted, more-or-less processed form) will be less than or equal to the interest rate, and, if less than the interest rate, will asymptotically approach the interest rate.

The existence of noninterest carrying costs associated with stock reserves (held in either raw or processed form, with the form determined by differentials in carrying costs and by the anticipated rate of change over time in extraction costs, as just discussed) will introduce a wedge between the rate of resource price increase and the interest rate, raising the emmetropic rate of price increase above the interest rate. However, unless, implausibly, real noninterest inventory carrying costs were to increase over time at a rate at least equal to the real interest rate, this wedge would contract over time as resource prices increased, i.e., noninterest costs would decline as a proportion of total costs, and the emmetropically required rate of price increase would decline, asymptotically approaching the interest rate.

Thus, extending the analysis to include not only the raw, *in situ* form of the resource and relaxing the restrictive assumption of zero noninterest carrying costs, the essential relationships between rates of resource price change and interest rates as indicators of myopia, emmetropia or hypermetropia are only marginally altered. Processing costs rising at a rate less than the interest rate would give rise to an emmetropic rate of resource price increase less than the interest rate, while positive noninterest carrying costs would imply a positive differential between the emmetropic rate of price increase and the interest rate. In both cases, however, over time the emmetropic rate of price increase would asymptotically approach the interest rate.

5. An Empirical Test of Myopia/Hypermetropia in Resource Markets

Fortunately, substantial data are available to permit suggestive, if indirect, tests of the presence of myopia or, conversely, of hypermetropia in primary resource markets. Here rates of change of U.S. resource prices are examined, with identification of the following specific resources:[15]

(1) bituminous coal (average value per ton, f.o.b. mine)
(2) crude petroleum (average value at well per bbl.)
(3) iron ore (average value per long ton)
(4) nickel (electolytic, cents per pound)
(5) copper (New York, electrolytic, f.o.b. refinery, cents per lb.)
(6) lead (New York, pig lead, cents per lb.)
(7) zinc (New York, slab zinc, cents per lb.)
(8) silver (New York, average price per fine ounce)

Mean annual rates of change of nominal prices and of real (relative) prices [i.e., resource prices relative to the Consumer Price Index (CPI)][16] are presented in Table 1 for the periods 1919 to 1981 and 1890 to 1981. These relatively long periods of time are examined because, as indicated above, the fundamental issue with reference to myopia/hypermetropia is the existence of *systematic* discrepancies between rates of interest and

[15]Sources of data are identified in the notes to Table 1.

[16]Virtually identical results are obtained when resource prices are deflated (a) by the wholesale price index and (b) by the implicit price deflator for gross national product (restricted to the period 1930 to 1981).

of resource price change. For this purpose it is necessary to abstract from from short-term, cyclical or aberrational changes in either interest rates or rates of resource price change.

For purposes of classifying resource markets as myopic (M), emmetropic (E) or hypermetropic (H), it is necessary to compare these rates of price change to an appropriate benchmark measure of the market interest rate. For the 1919 to 1981 period the mean annual yield of Corporate Aaa bonds (as reported by Moody's) is utilized, while the mean annual prime commercial paper rate is employed for the period 1890 to 1981. The advantage of these interest rates is that they are entirely "market determined," unlike, e.g., the prime bank lending rate (which is "administratively determined" and also not reflective of rates actually paid by borrowers, due to compensating balance requirements, discounts, etc.). However, their disadvantage for present purposes is that they represent relatively "riskless" yields, while the appropriate rate for purposes of the assessment of the efficiency of primary resource markets is one associated with assets the risks of which are comparable to the risks associated with resource portfolios. As can be seen in Table 1, which presents standard deviations as well as means for both rates of resource price change and interest rates, resources represent much higher risk assets, over time, than do representative portfolios of high-grade (Aaa) corporate bonds or prime commercial paper, with standard deviations of real resource prices one to five times greater than standard deviations of real interest rates. Of course, as implicitly suggested, a comparison of the variance of a single resource price change to the variance of the yield of a balanced portfolio of financial assets is, in fact,

Table 1.
Rates of Interest and of Resource Price Change

Period: Interest Rate:	1919-1981 Corporate Aaa Bonds		1890-1981 Prime Commercial Paper		Myopia (M) Emmetropia (E) Hypermetropia (H)
	Mean	Std. Dev.	Mean	Std. Dev.	
Nominal					
Interest rate	5.0%	2.4	4.5%	2.7	
Bituminous coal	4.6	15.3	4.5	15.0	E
Crude petroleum	6.6	21.5	6.4	22.7	M
Iron ore (1)	3.3	8.1	4.6	17.0	H/E
Nickel (2)	4.0	11.5	3.7	11.1	H/E
Copper	3.3	17.7	3.7	18.7	H/E
Lead	4.5	20.8	4.1	18.9	E
Zinc	4.1	17.5	4.5	24.3	E
Silver	6.7	26.4	4.8	22.9	M/E
Real					
Interest rate	2.1	5.2	2.0	5.1	
Bituminous coal	1.4	11.8	1.6	11.2	E
Crude petroleum	3.0	17.7	3.3	19.7	M
Iron ore (1)	0.3	6.3	1.7	16.1	H/E
Nickel (2)	1.0	10.3	0.4	10.4	H/E
Copper	0.2	16.3	1.0	17.5	H/E
Lead	1.2	17.9	1.2	16.5	E
Zinc	1.0	15.7	1.9	23.6	H/E
Silver	3.3	22.9	1.9	19.7	M/E

General notes: ***Hypermetropia*** is defined as rate of price change more than one percentage point less than rate of interest.
Emmetropia is defined as rate of price change within plus or minus one percentage point of rate of interest.
Myopia is defined as rate or price change more than one percentage point greater than rate of interest.

Specific notes:
(1) Time periods for iron ore are 1919-1981 and 1895-1981, respectively, with respective nominal (real) interest rates of 5.0 (2.1) percent and 4.4 (1.7) percent.
(2) Time periods for nickel are 1919-1981 and 1914-1981, respectively, with respective nominal (real) interest rates of 5.0 (2.1) percent and 4.1 (0.8) percent.

Sources: All resource prices, price indices and interest rates through 1970 are derived from U.S. Bureau of the Census, *Historical Statistics of the United States, Colonial Times to 1970* (Washington, D.C.: Government Printing Office, 1975). For the period 1971 through 1981 the source is U.S. Bureau of the Census, *Statistical Abstract of the United States*, [*1976, 1982-83*] (Washington, D.C.: Government Printing Office, [1976, 1982]).

inappropriate, since a representative portfolio of resources would exhibit a lower variance than would a single resource. However, it is probably still the case that even optimal resource portfolios constitute relatively high risk (high yield variance) assets by comparison to highly rated and easily traded financial assets. At the least, it can be argued that rates of return to physical capital (as measured, e.g., by returns to corporate equity), were they available over sufficiently long periods of time (which they are not), would provide a more appropriate (neutral) basis on which to test for the existence of myopia or hypermetropia. Utilization of lower risk Corporate Aaa bond and prime commercial paper rates, by understating the appropriate benchmark interest rate, will lend a bias in favor of a finding of myopia when markets are in fact emmetropic or, even, hypermetropic.

A further bias in the direction of a finding of myopia is introduced by the fact that noninterest carrying costs are ignored, i.e., implicitly assumed to be zero. However, especially in light of the fact that the resource prices refer in all cases to extracted and at least semiprocessed forms of the resource, this assumption is almost certainly violated. In addition to storage costs it is probable that at least some extracted and processed resources are also subject to physical deterioration.[17] While these costs are ignored here, it need not be the case that they are of only second-order significance.

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[17]Thus, for example, extracted tin ores are subject to a contagious "tin disease" caused by fungal attack, while iron and steel are subject to oxidization. Also, while the probability of theft (and/or insurance against theft) does not represent a cost to society, it is does constitute a cost to speculative investors, a cost which is probably greater if reserve stocks are held in extracted and processed or semiprocessed form.

While the utilization of a relatively low risk interest rate and the assumption of zero noninterest carrying costs introduce biases toward a finding of myopia, a bias in the opposite direction results from the fact that in all cases the resource prices refer to at least semiprocessed forms of the resource, for which positive extraction and processing costs are incurred. While, in principle, these costs need not imply an emmetropic rate of price increase less than the interest rate, because of technological change it would be expected that extraction and processing costs (controlling for the quality of the raw *in situ* deposit) would decline over time, while a rate of increase of these costs less than the interest rate would result, as discussed previously, in an emmetropic rate of price change which would also be less than the interest rate.

Whether the biases toward a finding of myopia, stemming from an inappropriately low measure of the interest rate and from the assumption of zero carrying costs, more or less than fully offset the probable bias toward a finding of hypermetropia, stemming from the failure to explicitly take into account (presumably declining) extraction and processing costs, cannot be determined *a priori*, and, unfortunately, data which would permit an empirical assessment of the magnitudes of these biases are not readily available. However, tests for myopia, emmetropia or hypermetropia ignoring these biases will at least provide suggestive evidence of the efficiency of intertemporal resource utilization.

In the final column of Table 1 resource markets are classified as myopic (M), emmetropic (E) or hypermetropic (H) on the basis of the relationship between the rate of price change (nominal or real) and the interest rate (nominal or real), defining emmetropia as a rate of price change equal to the interest rate plus or minus one percentage point, myopia as a rate of price change more than one percentage point greater than the interest rate, and hypermetropia as a rate of price change more than one percentage point less than the rate of interest.

Despite the possible biases incorporated in the present tests for myopia, emmetropia or hypermetropia, the somewhat suprising conclusion from the evidence presented in Table 1 is that myopia is clearly evident for only one resource, crude petroleum, and is observed in the more recent period but not over the entire period in the case of silver. However, hypermetropia is discovered over the 1919-1981 period (but not over the entire 1890-1981 period) for iron ore, nickel, copper and (marginally) zinc. If the stipulated interest rates understate the appropriate rates by only one percentage point (and continuing to allow a plus or minus one percentage point differential to represent emmetropia), myopia would not be found any of these resources, while hypermetropia would be determined for bituminous coal, iron ore, nickel, copper, lead and zinc, i.e., for six of the eight resources examined.

6. Conclusion

In summary, on the basis of evidence covering relatively long spans of time (63 and 92 years) minerals markets do not seem to be characterized by "pervasive myopia." Especially when the biases toward the "discovery" of myopia are considered, if anything these markets seem to tend toward hypermetropic misperception of the future. Thus, despite the apparently general view that markets tend to "sacrifice" the future for the present, the preponderance of the evidence is that market outcomes result in relatively efficient balancing of the interests of present and future, or, more accurately, in relatively efficient intertemporal utilization of exhaustible resources. Moreover, the suggestive evidence that in some markets the present may be inefficiently sacrificed for the future, or, again more accurately, that consumption possibilities in both the present and the future could be increased through higher rates of current utilization of resources, raises serious questions concerning the virtually total lack of attention to the possibility of this type of market failure in the relevant literatures.

The focus in this paper has been on the *classification* of individual markets as myopic, emmetropic or hypermetropic. Thus, the paper has not addressed the issue of the *causes* of either myopic or hypermetropic market failure. In conclusion it may be useful to note that the three most likely candidates as sources of myopic/hypermetropic market failures are (a) incorrect (presumably static) forecasts of technology, (b) incorrect forecasts of future reserve discoveries and (c) imperfect capital markets. The first two are more plausible as sources of hypermetropia, i.e., it is more likely that anticipations underlying the market determination of prices will underestimate resource-saving (-substituting) technological developments and future resource discoveries. Interestingly, in light of the apparently common assumption that markets are myopic, the only inherently plausible explanation for myopic market performance which comes readily to mind is capital market imperfection (implying rates of time preference systematically above market rates of interest, with nonprice rationing of access to borrowed funds). Thus, the present finding of a more general tendency toward hypermetropia is perhaps not surprising.[18]

[18]Note that monopoly of resource ownership, to which reference is frequently made in the context of intertemporal resource utilization, although somewhat complicating the analysis of intertemporal price determination, would itself not give rise to myopia, since even the monopolist must consider the present value of future monopoly profits; in fact, monopoly is a not implausible explanation for hypermetropia, in that the monopolist would not offer supplies, in any period, beyond the point at which the elasticity of demand was unity.