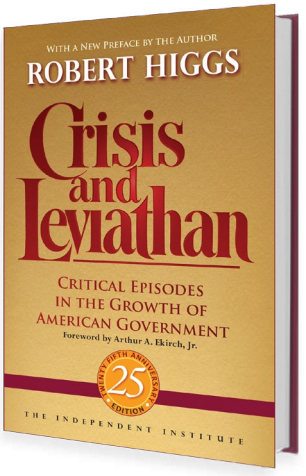
SUBSCRIBE NOW AND RECEIVE *CRISIS AND LEVIATHAN** FREE!

"***The Independent Review*** does not accept pronouncements of government officials nor the conventional wisdom at face value."
—**JOHN R. MACARTHUR**, Publisher, *Harper's*

"***The Independent Review*** is excellent."
—**GARY BECKER**, Noble Laureate in Economic Sciences

Subscribe to ***The Independent Review*** and receive a free book of your choice* such as the 25th Anniversary Edition of ***Crisis and Leviathan: Critical Episodes in the Growth of American Government***, by Founding Editor Robert Higgs. This quarterly journal, guided by co-editors Christopher J. Coyne, and Michael C. Munger, and Robert M. Whaples offers leading-edge insights on today's most critical issues in economics, healthcare, education, law, history, political science, philosophy, and sociology.



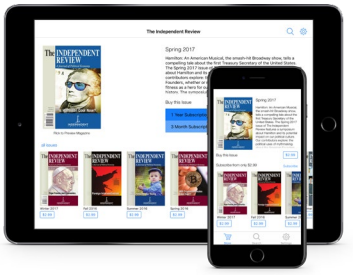
Thought-provoking and educational, ***The Independent Review*** is blazing the way toward informed debate!

Student? Educator? Journalist? Business or civic leader? Engaged citizen? This journal is for YOU!

*Order today for more *FREE* book options

SUBSCRIBE

Perfect for students or anyone on the go! ***The Independent Review*** is available on mobile devices or tablets: iOS devices, Amazon Kindle Fire, or Android through Magzter.



Download on the App Store | Available at amazon | Available on MAGZTER

INDEPENDENT INSTITUTE, 100 SWAN WAY, OAKLAND, CA 94621 • 800-927-8733 • REVIEW@INDEPENDENT.ORG PROMO CODE IRA1703

Resource Exhaustibility

A Myth Refuted by Entrepreneurial Capital Maintenance

JOHN BRÄTLAND

The concept of *myth* is defined as "an unproved collective belief that is accepted uncritically" (*Random House Dictionary* 1969, 946). One such myth is the idea that extractive resources are exhaustible in an economic sense. In this article, I examine extractive resource availability as it is affected by what is commonly referred to as "resource exhaustion." In part, the myth has been manifested in the long-held notion that all extractive resources are subject to eventual exhaustion and that this prospect should be cause for public alarm.[1] This alarm has conditioned theoretical thinking about public policy in connection with sustainability (Brätland 2006) and has prompted policy discussion of government subsidies for alternative fuels. An examination of the myth reveals, however, that it has its origins in neglect and ignorance of entrepreneurial capital maintenance as it operates in the economics of extractive resources.

The economics profession has perpetuated the myth to a major extent. First, it has persistently focused on imagined issues surrounding global resource exhaustion. Second, it has embraced a traditional but erroneous definition of capital as a physical

John Brätland is a senior economist with the U.S. Department of the Interior in Washington, D.C.

1. Aggregate resource fixity is the principal focus of Robert Bradley's (2007) extensively researched paper. Bradley makes reference to Morris Adelman, who has debunked the notion of fixed aggregates stocks of an extractive resource. See Adelman 1993, xiv, 241–42, and 1995, 11–19. Unfortunately, Adelman's otherwise excellent work contains no legitimate entrepreneurial theory of capital. His perspectives are examined later.

The Independent Review, v. XII, n. 3, Winter 2008, ISSN 1086–1653, Copyright © 2008, pp. 375–399.

grouping of produced durable goods. Goods grouped in such a definition may typically include equipment, buildings, inventory, and so forth. Defining capital in this way, however, admits no rational framework for maintenance and in fact has played a significant role in fostering the exhaustion myth. In a coherent theory, capital is always an entrepreneur's own monetary reckoning of the worth of his particular business plan. Capital is not a physical entity; it is not a collection of physical capital goods, even though all entrepreneurial plans involve the use of capital goods (Kirzner 1996, 124). Capital goods come into existence essentially through the actions of savers and the plans undertaken by entrepreneurs. They represent the assets that the entrepreneur has marshaled in the pursuit of a plan.

As applied to extractive-resource renewal, capital maintenance is essentially speculative action undertaken to maintain entrepreneurial income. Viewed in a planning context, income can be seen as part of a speculative plan focused on the portion of expected gross receipts that can be withdrawn from the enterprise while at the same time maintaining capital. Hence, from the entrepreneur's perspective, prospective income must be consistent with the requirements of capital maintenance. Because capital is the corollary of income, capital maintenance necessarily revolves around the success of the entrepreneurial plan in maintaining the extractive enterprise's income. That income, however, is never a certainty in an entrepreneurial environment; a previously implemented plan may yield a lower income than was expected.[2] In such an event, future plans must be adapted to the conditions perceived to exist in the market. Hence, the income earned by the entrepreneurial firm depends on its selection and implementation of plans that take into account conditions of uncertainty and economic change.

Exhaustibility has relevance only within the context of a particular entrepreneur's plan; economic exhaustion motivates investment in capital goods that maintain the value of the entrepreneurial enterprise. The exhaustion's only importance arises in the process by which the entrepreneur seeks to make and develop new discoveries. The entrepreneur undertakes these efforts because of declining returns from deposits already being depleted. The extractive firm maintains income through a perpetual but speculative process involving a continual restructuring of capital goods. It is never in a state of equilibrium with respect to its holdings of capital goods, of which extractive-resource deposits may be only a part. This restructuring process requires entrepreneurial judgment in selecting the respective stages of the production process in which to invest. The stages include: (1) land-surface access, (2) exploration, (3) development, and (4) resource extraction. To the extent that these speculative efforts succeed, capital is maintained. However, as the following discussion emphasizes, investment

2. To the extent that Hotelling rents exist, they are subsumed in entrepreneurial income. In a changing, uncertain disequilibrium world, the existence or possible recovery of such rents is inseparably tied to entrepreneurial action and cannot be quantitatively distinguished from entrepreneurial income as a whole (Brätland 2000, 15).

processes that are narrowly focused on a mechanistic cycle of physical replacement are not necessarily valid examples of successful capital maintenance.

Capital maintenance by extractive enterprises necessarily implies that minerals, of whatever sort, will never be exhausted unless entrepreneurial action is somehow impeded or precluded. Hence, future cessation of the production of an extractive resource will occur not because of its exhaustion, but because either the intended or the unintended consequences of human activity have eliminated the prospects for profitable resource renewal. In one scenario, material substitutes may arise. The availability of such substitutes might cause consumers to be unwilling to pay for the consumer goods or services produced from extractive outputs. More troubling scenarios are also evident: (1) fragmented property institutions may impede entrepreneurial firms' ability to manage resource deposits as capital assets; and (2) government policies may coercively foreclose access to lands that would permit entrepreneurial replacement of extractive resources. For example, government intervention designed to nationalize resources and to impede access to lands for exploration will thwart the replacement processes necessary for extractive enterprises to maintain capital.

Exhaustible Resources in Neoclassical Economics

The exhaustion myth arose in public-policy hysteria over coal availability in nineteenth-century England and was revived in the panic over world oil supplies in the twentieth century. Neoclassical economists have responded to this public anxiety by contriving formal models of resource exhaustion and by attempting to apply these models to energy issues and to the economics of intergenerational sustainability. Despite impressive efforts to incorporate resource renewal into formal equilibrium frameworks, these undertakings have generally displayed aggregative thinking and neglected the speculative process by which entrepreneurs actually maintain the capital value of the extractive enterprise.

Jevons, Gray, and Hotelling

The exhaustion assumption as it legitimately applies to individual resource deposits has somehow become a metaphor for global exhaustion.[3] It is an implicit but largely unexamined premise in the theory and public-policy proposals about the future availability of extractive resources. In contrast, the idea that extractive resources are always replaceable capital goods has received little attention. An important reason for the relative neglect of extractive-resource replacement is that the earliest work by economists for the most part ignored the entrepreneurial capital maintenance undertaken by extractive enterprises.

3. For a more general and wide-ranging discussion of the work published by these and other economists, see Bradley 2007.

Although W. Stanley Jevons, Lewis C. Gray, and Harold Hotelling applied certain concepts related to capital, they never broke out of the mechanistic neoclassical mold by introducing the entrepreneur.[4] Note the reference to "exhaustion of resources" in the titles of each of their major works on the subject (Gray [1914] 1967; Hotelling 1931). Stanley Jevons's 1865 analysis of expected future coal shortages in England touched off what some have called a "coal panic" (Bradley 2007, 65). The oil panic of the 1970s renewed interest in Hotelling's 1931 article, with its premise of global exhaustion manifested in the rising prices of increasingly scarce extractive resources. In other writings, such as Gray's 1914 study (reprinted in 1967), exhaustion entered by way of increasing costs that occurred as a result of cumulative extraction (Morse 1976, 236–40). Missing from these analyses, however, is an allowance for or a description of an entrepreneurial response to changes in extraction cost and the process by which such changes prompt action to maintain capital by replacing the depleting deposits. Even late in the twentieth century, the exhaustion myth persisted in neoclassical modeling of intergenerational sustainability.

The Economics of Sustainability and Its Theory of Physical Capital

Intergenerational sustainability theory is premised on the urgency of formulating a "principle of investment" to maintain a "capital stock" for the benefit of future generations. The presumed exhaustibility of extractive resources has spawned the notion that unborn generations will experience declining levels of consumption. For both John Hartwick, a professor of economics at Queen's University in Canada, and Robert Solow, a professor of economics at MIT, exhausting resources implies a decline in the "capital stock." For them and other economists, the "investment principle" must be applied as a solution to the "sustainability problem" associated with the exhaustion of resources. A principal tenet of this principle is that investment must be focused on replacement of the "physical capital" embodied in the exhausting resource stock. Hartwick posits that the current generation, as an acting entity, must "invest all profits or rents from exhaustible resources in reproducible capital such as machines. . . . This injunction seems to solve the ethical problem of the current generation shortchanging future generations by 'over-consuming' the current product currently ascribable to current use of exhaustible resources. Under such a program, the current generation would have an obligation to convert exhaustible resources into machines and to 'live off' current flows from machines and labor" (1977, 972). Hartwick reprises this prescription in his more recent book (2000, 88–101).

Robert Solow enthusiastically concurs with Hartwick in observing that "the policy of investing resource rents in reproducible capital suggests irresistibly that some appropriately defined capital stock is being maintained intact and that consumption

4. Concepts related to capital include present-value discounting and the allocation of use over future periods.

can be regarded as the interest on that stock. This interpretation turns out to be quite right" (1986, 146). The Hartwick-Solow prescription would ostensibly involve governmentally controlled reinvestment of resource rents to achieve a golden rule of "physical capital maintenance." In affirmation, Geoffrey Heal of Columbia University has actually asserted that the Hartwick-Solow prescription "achieves the highest possible level of utility for the least well-off generation. Remarkably, it also achieves the highest feasible constant level of utility given the economy's initial stocks of capital and resources" (1998, 8).[5]

The Hartwick-Solow prescriptions, however, are untenable for several reasons. First, this absurd notion is grounded in a physical (real) theory of capital that is completely useless in any rational reckoning of capital replacement. True to form, the neoclassical theorists embrace the traditional supposition that increased current use of the exhaustible resource implies increasing physical scarcity for future generations. Second, the Hartwick-Solow perspective largely ignores market uncertainty and the fact that scarcity rents do not appear as objective data, as they would in some unattainable equilibrium (Brätland 2000, 12–15). In real-world markets, scarcity rent, like the depreciation of any private capital asset, is always an entrepreneurial judgment that must take account the market's uncertain future. Third, the prescription disregards the incentives facing individual entrepreneurs confronted with the implications of site-specific resource exhaustion and the need to maintain capital (Brätland 2006, 39).

"Optimal Renewability": Stephen McDonald's Contribution

The late Stephen McDonald, who was a professor of economics at the University of Texas, deserves separate mention inasmuch as he avoided the exhaustion myth by assuming that extractive resources are "renewable" (McDonald 1967).[6] McDonald formulated an elegant, highly abstract equilibrium theory that defined (1) an optimal rate of use of a "known stock" reflective of an optimal rate of renewal and (2) an optimal rate of renewal reflective of an optimal rate of use of the known stock. Referring to *renewal* as the rate at which resources are "appropriated from the unknown to the known stock," he proceeded first by placing the economics of conservation within a traditional neoclassical version of capital theory. "The approach taken here is . . . treating the economics of conservation as a particular application of the theory of capital and its use. Capital theory is addressed to the time dimension of the economizing problem, i.e., to the efficient allocation of satisfactions among different points in time. . . . As a form of action, [conservation] is defined as action designed to

5. The notion of utility as experienced either by an individual or by a generation of people is absurd. Valuation itself can never be more than a *subjective ranking on a single ordinal scale* established only by an individual human being at the moment a decision is made. The problem is not simply that utility is unmeasurable, but that it does not exist.

6. See also McDonald 1971, chaps. 4, 5, and 6.

achieve or maintain the optimum time distribution of use of a natural resource" (1967, 271–72). McDonald describes a tandem optimality in both the rate of use of a known stock of the resource and the rate of renewal that incorporates discovery and development of new deposits:

> Where the known stock of a particular resource is renewable through exploration . . . the optimum time distribution of use embraces two separate but interrelated levels of optimization. The first pertains to the rate at which resources are devoted to the renewal effort, hence given the discovery function, the rate at which the remaining unknown stock is appropriated into the known stock. The present value resulting from the optimum time distribution of use of the known stock in relation to the expected costs of renewal affect the rate of the renewal effort. The time distribution of use of the whole stock, known plus unknown, is optimal when the marginal yield on postponement of use in the known stock and the marginal yield on exploration for renewal are both equal to the marginal rate of time preference adjusted appropriately in each case for risk and uncertainty. Expected costs of renewal reflected in expected future prices affect the optimum time-distribution of use of the known stock. . . . Conservation, as defined, pertains to the whole stock and thus [to] optimality at both known stock and the renewal level. (1967, 272–73)

Although McDonald makes several questionable references to "resource stocks," known and unknown, one can reasonably argue that he avoids the exhaustion myth because the dual "optimality" he describes is not premised on any type of ultimate exhaustion. However, his formulation glosses over several critical realities that bear on the maintenance of capital in extractive enterprises. McDonald clearly had in mind an equilibrium world in which speculative action on the part of entrepreneurial enterprises plays no realistic role in the process of capital maintenance or renewal. Moreover, his reference to "optimum time distribution of use" is ostensibly premised on some already-known, deterministic, equilibrium view of markets in the future.[7] Of course, no entrepreneur can know the future of any market. In addition, this deterministic view is invalidated by the nonexistence of the "discovery function" to which McDonald makes reference. Discovery is contingent on site-specific, entrepreneurial assessments of risk and reward associated with investments undertaken at particular locations.

McDonald's "ivory-tower" depiction lacks a practical appreciation that whether

7. In a later publication, McDonald took a position more reflective of the dynamics of actual markets: "the optimum time-distribution of production is defined for one point in time only. It changes as its determinants change from point to point in time. In particular, it changes with every change in current and expected costs and prices. . . . Thus, continuously maximizing net present value (continuously conserving) *requires flexible adjustments* in the time-distribution of production as the economic values reflecting sacrifice and gains of satisfaction (costs and prices) change over time" (1971, 83–84).

resources are plentiful or scarce at an aggregate level depends on the plans undertaken by individual entrepreneurs to replace particular depleting resource deposits. A new deposit of an exhaustible resource is largely an entrepreneurial judgment brought to bear in the plans of each extractive enterprise. For a pessimistic entrepreneur, the value of a deposit may be low, whereas for an optimistic entrepreneur it may be high. In an entrepreneurial world of change and uncertainty, an individual resource deposit will not have the same economic significance to all competing entrepreneurial enterprises. Moreover, these assessments of economic significance will change over time. Resource renewal bears solely on the plans that individual extractive enterprises implement to maintain capital by replacing particular depreciating capital goods. The extent to which resource renewal represents renewal of capital depends squarely on the success of the extractive enterprise's own business plan. When we focus on the entrepreneur, which as theorists we should, "optimal renewal" of global resource stocks thus appears to be a nonsensical notion.

Perspectives of the Austrian and Institutionalist Schools

The exhaustion myth has been characterized recently as evidence that economists have explicitly or implicitly worked within a "fixed-supply framework." Did leading economists of the Austrian school of economics work within such a framework? The answer is yes, according to Robert Bradley's interpretation of the work done by Murray Rothbard, Friedrich Hayek, and Ludwig von Mises (2007, 71). In his critique of the Austrians, Bradley identifies Erich Zimmermann as an example of an economist who developed a distinctively "subjective approach" to the definition and availability of resources. In so doing, according to Bradley, he avoided this so-called fixed-supply framework. Bradley further asserts that Zimmermann's insights are absent from the thinking of these Austrian economists and that Zimmermann's views on institutional heterogeneity and adaptability fill an evident lacuna in the development of a truly Austrian theory of extractive resources (2007, 79). As definitive categorizations of these four economists, however, Bradley's claims are open to serious challenge.

Austrians Economists and the Question of the "Fixed-Supply Framework"

Of the three Austrian economists Bradley mentions, only Rothbard seems to have resorted to theoretical interpretations ostensibly reliant on fixed-supply assumptions. Rothbard is thought to have worked within such a framework because of his attempt to draw a sharp distinction between "permanent, nonreproducible land" and capital goods, which he defined as being nonpermanent and therefore as needing to be reproduced again to continue to yield productive services (2004, 215, 299). He then placed depletable resources in a special category: "Resources that are being depleted obviously cannot be replaced and are therefore land, not capital goods. . . . Here the

factor is definitely original and nature given; it cannot be produced by man . . . though non-permanent, [such factors] *cannot* be reproduced by man despite their depletion. Therefore, the natural resource comes as a special division under the land category. . . . The point is that resources subject to depletion cannot be replaced, much as the owner would like to do so" (2004, 484–97). One infers that Rothbard was focused on aggregate or global stocks in coming to his conclusions, but in so doing he failed to note that the extent of such a stock depends on the capital-maintenance actions of entrepreneurial enterprises. In taking this position, Rothbard was obviously never able to treat extractive mineral resources as capital goods that are renewable in the implementation of entrepreneurial plans.[8]

Hayek, however, saw extractive mineral resources as capital goods that could be replaced by "produced means of production" in efforts to maintain income.[9] But what is meant by the phrase "produced means of production"? The answer to this question is necessarily a matter of inference. Hayek's exact language is found in the following statements: "[M]ineral deposits are inevitably exhausted by their use and cannot possibly render the same services forever" ([1941] 2007, 72); and, "[i]f income is to be maintained permanently at the higher level which the wasting natural resources make possible, these resources will, as they become exhausted, have to be replaced by produced means of production" (102). Does this comment confirm that Hayek worked within a fixed-supply framework? The wording in itself does not provide a conclusive answer. Site-specific exhaustion does not preclude entrepreneurial investment to maintain capital through investment in the replacement of resource deposits. Moreover, his reference to "produced means of production" might as easily include the productive activity necessary to discover and develop new deposits of an extractive resource. In other words, a deposit, whether new or old, is legitimately a produced means of production because both exploration and development are distinct stages of a production process. Does this interpretation reflect Hayek's intended meaning? Such an inference hinges on the extent to which Hayek's concept of capital legitimately accommodates an approach to entrepreneurial capital maintenance that allows for the actual replacement of exhausting deposits of resources.

How did Hayek define capital? His focus on income maintenance leads one to conclude that he did not treat capital as an aggregation of physical things or capital goods and suggests that he viewed it as an entrepreneur's speculative monetary reck-

8. Nonetheless, in later writings Rothbard recognized that society's resource base shifts and evolves as consumer tastes change and new technologies emerge ([1973] 2006, 310).

9. Rothbard, with his focus on the unreplaceability of such resources, mistakenly called Hayek to task for misconceiving "the issue as being one of maintaining a 'constant income stream' instead of classifying a physical concrete good" (2004, 497). On Hayek's designation of resource deposits as capital goods, questions arise about his use of the term *wasting* (Hayek [1941] 2007, 105). By this term, he refers simply to the fact that capital goods, whether in the form of equipment or resource deposits, are nonpermanent and subject to depreciation (waste) through use. Hayek explains that "[w]hat determines the common characteristics of capital goods is not that they can be reproduced but how they are used: namely that they can be made to yield all their services in the comparatively near future" ([1941] 2007, 106).

oning of the value attached to a business plan. He even employed the term *capital good,* ostensibly reflecting his intent to make the crucial distinction between such goods and capital itself. But then one reads the following definition: "The term *capital* itself . . . will accordingly be used here to designate the aggregate of those non-permanent resources which can be used only in this indirect manner to contribute to the *permanent* maintenance of the income at a particular level" ([1941] 2007, 75, emphasis in original). The designation of capital as a physical aggregate (stock) suggests a retreat into a type of static equilibrium world in which speculative entrepreneurship has, at best, an ambiguous role in the process of capital maintenance. Furthermore, Hayek's numerous references to "permanent maintenance of income" seem to be grounded in a static perspective. As Mises emphasized, however, a permanent or certain income is an impossibility in an entrepreneurial world ([1949] 1998, 390). Hence, on the subject of extractive-resource renewability, Hayek was not necessarily working within a fixed-supply framework, but in defining capital as he did, he seems to have placed himself within an analytical framework that obscures a speculative capital maintenance that accommodates replacement of resource deposits.[10]

Even less evidence supports the contention that Mises worked within a fixed-supply framework. One can note Mises's statement that "[t]he useful mineral substances contained in the soil are limited in quantity" ([1949] 1998, 637), but this statement is tautologically true simply because the earth's total mass is finite, and it has little bearing on the economics of resource availability. One is hard pressed to infer a fixed-supply framework from a thoughtful reading of any Mises's writings. Bradley quotes the following statement by Mises: "The deposits of mineral substances and their exploitation are not characterized by features that would give a particular mark to human action dealing with them" (from Mises [1949] 1998, 637).[11] What does the phrase *particular mark* mean in his sentence? At best, Mises's intended meaning is obscure. In general, one's best conjecture of Mises's position with respect to the availability of any good is that supply is contingent on action taken to exploit the speculative, subjectively reckoned net gain from the pursuit of additional production. Moreover, Mises never used the term *nonrenewable* with respect to extractive or mineral resources. In any case, Mises's views on resource renewability can be gleaned more accurately from an examination of his views on capital and the entrepreneurial enterprise.

Erich Zimmermann's Resource Economics

Zimmerman belonged to what is now categorized as the early institutionalist school of economics, whose leading lights included W. C. Mitchell and John R. Commons.

10. Bradley seems to acknowledge as much in his own description of Hayek's stance (2007, 73).

11. Bradley offers the following observation in apparent contradiction of his own contention that Mises worked within a fixed-supply framework: "Mises' theory of minerals is thus opposed to that of Harold Hotelling. . . . The history of minerals to Mises points toward enough prospective abundance so that the macroeconomic does not impinge on the microeconomics of human action" (2007, 71).

This school tended to eschew formal economic theory and to focus on the role of institutions. Zimmermann ([1933] 1951) offered interesting insights into the definition and availability of resources that seemed to depart from neoclassical assumptions. However, his later work on petroleum conservation (1957) appears to be grounded in more traditional thinking. Nonetheless, Bradley's recent commentary suggests that Zimmermann managed to transcend the fixed-supply framework in a way that eluded the Austrian economists (2007, 77–82). Did Zimmermann's views on the availability of extractive resources represent a significant advance over those of Mises, for example? The answer appears to be no. One might add that in some respects Zimmermann's observations represent a retrogression from Mises's thinking. Note, for example, the following statements:

> From the standpoint of conservation, resources are divided into two categories, (1) renewable or flow resources, . . . and (2) non-renewable or found (or stock) resources which are generally used up . . . [for example,] petroleum . . . is unavoidably destroyed or dissipated in use. (Zimmermann 1957, 6)

> [P]etroleum, like most minerals, is a non-renewable earth material. The total amount of petroleum existing on this planet is not known but is believed to be far smaller than the total amount of coal. . . . In spite of the fact that the total amount of petroleum is unknown and its nonrenewable supply inevitably diminishes through use, modern civilization . . . is coming to depend on ever larger amounts of petroleum products. (1957, 51–52)

Granted, these quotes are plucked out of context, just as were those from Mises cited earlier. A more balanced representation of Zimmermann's "open-ended" perspective on resource availability is yielded by the following remarks, quoted by Bradley: "Resources are means to ends. Means derive their meaning from the ends which they serve. Ends suggest purpose. Purpose springs from the human mind, from the mind of individuals. Resources therefore reflect the subjective appraisal of those who purposefully choose means to accomplish given ends" (qtd. in Bradley 2007, 78). Comments of this sort prompt Bradley to describe Zimmermann's perspective as a "subjectivist, mind-centered approach" to the definition and availability of mineral resources (2007, 63). However, it turns out that Zimmermann's observations are a virtual paraphrase of remarks made by Mises, though Mises uses the term *means* rather than *resources*. Examples include: "An end is everything that man aims at. A *means* is everything which acting man considers such" (Mises [1949] 1998, 93); "[a]cting man transfers the valuation of ends he aims at to the *means*" (201); and "[a]cting man does not look at his conditions with eyes of a historian . . . his only concern is to make the best use of the means available today for the best possible removal of future uneasiness" (477). Mises realized that means (resources) become capital goods only

in the context of entrepreneurs' plans to maintain capital and serve the needs of consumers. For Mises, *capital* is the entrepreneur's net valuation or appraisal of a business plan, and *means* or *resources* take on their true significance only in the context of entrepreneurial planning (512). Hence, it is misleading and inaccurate to describe Zimmermann's thinking on these issues as a significant improvement over Mises's thinking.

In other ways, however, Zimmermann seemed to retrogress with respect to general issues critical to resource availability. Although he makes occasional reference to entrepreneurship and scientific advance, he is dismissive and even disdainful of the requisite market institutions critical to resource availability. Note, for example, the statement: "If conservation were identical with economy, we could safely rely on private initiative and other moving forces of the economic price system. But, if on the other hand, the essence of conservation is the sacrifice of present economic interests on behalf of posterity, the profit motive cannot be relied upon to assure conservation, and social controls must be resorted to" ([1933] 1951, 810). This statement is followed by some perplexing and ostensibly self-contradictory remarks:

> Those advocates of laissez faire . . . rightly emphasize the fact that corporations are in a better position to conserve natural resources than are individuals and partnerships. . . . As long, however, as corporate management considers public interests as merely incidental to private interests, we can hardly expect the final solution of the conservation problem from voluntary decisions of directors of corporations. . . . *[A]s long as the maximization of profit remains the cornerstone of acquisitive society and capitalistic economy, corporations will retain their interest in scarcity as a creator of economic value.* ([1933] 1951, 810, emphasis added)

Mises, in contrast, provides a more thoughtful perspective:

> What improved and still improves the fecundity of human efforts is the progressive accumulation of capital goods without which no technological innovation could ever be practically utilized. . . . What transformed the world of horse-drawn carriages, sailing ships and windmills step by step into a world of airplanes and electronics was the laissez faire principle. . . . Large savings continuously in search of the most profitable investment opportunities are *providing the resources* needed for rendering the accomplishments of the physicists and chemists utilizable for the improvement business activities. . . . The much decried acquisitiveness of the promoters and speculators was intent upon applying the accomplishments of scientific research to the improvement of the masses' standard of living. ([1962] 2006, 114–15, emphasis added)

Although Zimmermann seemed to be enthusiastic about the role of entrepreneurship in availing society of resources, his open skepticism of the private-enterprise system

reveals another blind spot in his thinking about the role of certain market institutions. As an institutionalist, he devoted little attention to formal economic theory. Yet a focus on certain aspects of theory is critical to an understanding of the role of particular institutions in assuring resource availability. One such institution is the firm or entrepreneurial enterprise itself because it is the institutional embodiment of the entrepreneurial plan. In a general sense, Zimmermann's comments on firms are only ad hoc in that he makes reference to specific companies, but he neglected the theory of the firm as an institution even though it plays an indispensable role in the use and replacement of depreciable capital goods assembled in pursuit of the entrepreneurial plan (Lewin 1999, 162–65). Under market uncertainty and economic change, extractive firms perform the indispensable role of allocating the services of particular nonpermanent capital goods between time periods. More to the point, deposits of extractive resources are depletable capital goods that must be replaced in some form if the capital value of the enterprise is to be maintained. The entrepreneurial enterprise provides the institutional framework in which replacement plans can be implemented. By ignoring the firm as a theoretical entity, Zimmermann failed to provide an institutional connection between resource availability and entrepreneurship itself.

Extractive Enterprises' Capital Maintenance and Speculative Plans

The principal goal of any extractive enterprise is the speculative earning of entrepreneurial income. The entrepreneurial enterprise exists, however, only in a disequilibrium world in which markets are subject to uncertainty and change. Hence, plans are necessarily speculative in nature: their success is never assured. To examine the economic process by which deposits of resources are replaced, one must focus not on the resource itself, but rather on the extractive firm and the alternative speculative strategies from which it must choose in its efforts to maintain capital.

Plans and the Distinction Between Capital and Capital Goods

The neoclassical focus on equilibrium and aggregate capital stocks has tended to obscure the entrepreneurial enterprise's role in the economics of extractive resources. In a more general sense, the focus on equilibrium has fostered a theory unmindful of any need to make a distinction between capital and capital goods. For example, a typical definition of *capital* is the following: "capital consists of durable produced goods that are in turn used in production. The major components of capital are equipment, structures and inventory" (National Research Council 1999, 208). But do these listed things really represent "capital"? No. The list is only a catalogue of capital goods. By neglecting the entrepreneurial enterprise and denying the realities of

market uncertainty and disequilibrium, any neoclassical distinction between capital goods and capital becomes only a rhetorical formality. What is a coherent definition of *capital?* Ludwig von Mises offers the clearest definition: "*Capital is the sum of the money equivalent of all assets* [capital goods] *minus the sum of the money equivalent of all liabilities as dedicated at a definite date to the conduct of the operations of a definite business unit.* It does not matter in what these assets may consist, whether they are pieces of land [inclusive of extractive resources], buildings, equipment, tools, goods of any kind and order, claims, receivables, cash or whatever" ([1949] 1998, 262, emphasis added).

When Mises employs the phrase "money equivalent of all assets," he has in mind the entrepreneur's monetary imputation of the capital goods' marginal worth within the context of his business plan. Hence, capital also represents the entrepreneur's best speculative judgment of the present worth of prospective income from a business plan that employs particular capital goods. To this extent, capital simultaneously represents both a balance-sheet reckoning and an entrepreneurial idea. As Mises notes, "its place is in the human mind. It [capital] is a mode of looking at the problems of acting, a method of appraising them from the point of view of a definite plan" ([1949] 1998, 512). The business unit to which Mises makes reference is an entrepreneurial enterprise whose purpose is to implement and pursue a business plan. In the neoclassical framework, in contrast, business plans play no particular role because they are superseded by the conditions of an assumed equilibrium.

Capital goods come into existence first through the decisions of savers and then through the actions of entrepreneurs who marshal their use for the implementation of chosen business plans. For the extractive enterprise, a balance-sheet tabulation of capital goods includes mineral deposits of extractive resources. As noted earlier, however, a particular resource deposit has differing importance to competing enterprises. Imputations of resource value are not revealed as objective data in business audits; one must always be aware that they are conditioned by an entrepreneur's judgment about future market conditions. Hence, the balance-sheet accounts are, in fact, speculative judgments or refined conjectures regarding the future income that the entrepreneur expects to earn in the market by employing capital goods in pursuit of a plan.

Income Maintenance as Capital Maintenance for Extractive Enterprises

The principal function of capital accounting is to provide a framework in which the entrepreneurial enterprise can choose between alternative actions and investments in its efforts to earn income: "[t]he question [that capital accounting] answers is whether a certain course of conduct increases or decreases the productivity of our future exertions" (Mises [1949] 1998, 511). When viewed in the context of accounts, *income* appears as the correlative of *capital.* To the extent that an extractive enterprise earns income, its capital can be maintained. To the extent that the enterprise makes

prudent choices in its investment decisions, it earns income.[12] But the word *choice* necessarily implies that the profit-sustaining capacity of investment in capital goods is only as good as the entrepreneurial plan of which they are a part. Plans can fail. The entrepreneurial firm is never presented with a situation in which it can make choices mechanically on the basis of objective data. Entrepreneurial judgment is required at every step.

Capital maintenance for the extractive enterprise entails speculative judgment with respect to depreciation or depletion of particular capital goods. The enterprise must make choices with respect to the replacement of depleting resources, the income-generating potential of which is diminished by current extraction. In this speculative reckoning, the enterprise attempts to strike a balance between its valuation of marginal returns obtainable from current extraction and its valuation of (discounted) marginal future returns relinquished, or of *user cost*. User cost reflects a personal outlook that may be colored by optimism or pessimism, boldness or timidity, at any particular moment (Lachmann 1986, 66–67). Hence, replacement of capital goods, such as resource deposits, turns on a fundamentally speculative reckoning. *An awkward reality of this process is that subsequent events may reveal that the physical replacement of a particular capital good, such as a resource deposit, did not successfully maintain capital.* In other words, even though the undertaking may have achieved a physical success, the events of the market may reveal the investment to be a loss for the extractive enterprise. As Ludwig Lachmann has emphasized, these decisions are speculative because the consequences of actions cannot be known with certainty. Plans for capital maintenance may be revealed as unsuccessful after they have been carried out.

Choice from among Alternative Speculative Strategies to Maintain Capital

Morris Adelman has avoided many of the errors made by other economists who have worked on what has been erroneously labeled the "economics of exhaustible resources." His efforts represent a dramatic improvement over previous work in the economics of extractive resources. First, Adelman resoundingly debunks the notion of aggregate resource stocks and the presumption of exhaustion and increasing global scarcity. Second, he focuses strictly on the actions of firms making choices about the least-expensive means of replacing a unit of the resource produced in the present. Third, his analysis goes partway in considering how the incremental expenses of one replacement alternative are affected by the firm's choices made at the margin with

12. From an ex post perspective, entrepreneurial income can be described as the difference between the entrepreneur's ex ante judgment of what the resources are worth in their "best" relinquished use and the ex post revenues generated from the plan actually implemented (Lewin and Phelan 2000, 71).

respect to all resource-replacement strategies. In essence, his criterion for "optimality" centers on the "least costly strategy" for replacing a unit of the resource produced and sold today. Speaking of petroleum resources, Adelman observes:

> The cost of creating reserves by various methods should approach equality at the margin. The cost of creating new reserves through more extensive or intensive development of known pools can be called marginal development cost and should in equilibrium equal marginal finding cost, which should equal marginal user cost. Discovery, development and purchase are . . . alternative methods of acquiring reserves. If the operator chooses to develop a known pool more extensively, increased development cost is the penalty for using not holding. He should not incur a penalty greater than the value of an undeveloped barrel, i.e., user cost (1993, 243).[13]

One should note that Adelman treats opportunity cost as essentially an objective value. To this extent, his approach to cost implicitly minimizes or eliminates the role of entrepreneurial judgment because it rests on equilibrium assumptions in which the future is essentially known. Financial outlays are assumed to represent the objective opportunity cost involved in committing to a certain course of action. However, in a changing, uncertain, disequilibrium environment, this approach to opportunity cost is untenable and even unscientific (Buchanan 1969, 49–50). Opportunity cost is necessarily the extractive firm's subjective valuation of what is relinquished in undertaking one action as opposed to another. Hence, empirical examination by an external observer is useless in attempting to establish the extent to which equality emerges in the marginal cost of resource-replacement options. These opportunity costs are subjective and unique to individual entrepreneurial enterprises.

Adelman's approach to these issues, however, is not focused on capital maintenance. Rather, it is a mechanistic process geared to the physical replacement of a particular resource at a largely known minimum "expense." In other words, his analysis is essentially a theory of the physical replacement of a single capital good and the monetary expense associated with such replacement. It suggests an approach to resource replacement that may not necessarily constitute capital maintenance for the entrepreneurial firm. Adelman's replacement scheme is focused on cost minimization, which in itself is a misleading criterion for choosing the actions necessary to maintain capital. The simple replacement of resources or capital goods will not necessarily achieve that objective. Alternative strategies to maintain entrepreneurial capital include a comparison of the present worth associated with income expected to accrue to the enterprise over differing time horizons. In making these comparisons, the firm makes subjective judgments of the respective risks and uncertainties associated with

13. For Adelman, user cost per unit of the discovered but undeveloped resource is the difference between the in situ value of the developed resource and the prospective development cost per unit.

each strategy. At any moment, the following investment strategies are usually available to the extractive firm:

1. Purchase leases (surface access) and immediately undertake exploration investments to find new deposits, then proceed directly with development and extraction of newly discovered deposits.[14]
2. Immediately develop and commence extraction of already discovered resource deposits on leases already under the firm's control.
3. Purchase from other firms leases containing deposits that have already been developed; then immediately undertake extraction of these deposits.
4. Purchase from other firms those leases containing discovered but undeveloped deposits, then immediately embark on the development and extraction of these deposits.
5. Engage in speculative delay with respect to *(a)* acquisition of additional exploration rights (leases), *(b)* additional exploratory efforts on owned leases, *(c)* investment in development on owned leases, and *(d)* production of the resource from developed leases already owned by the extractive enterprise.
6. Extract deposits but maintain capital by reinvesting proceeds in capital goods that *may not* be directly related to the extraction of resources.

As noted, each of these strategies for capital maintenance involves an uncertain time profile of prospective revenues and financial outlays, so that choices made from among these options must involve due allowance for time preference and uncertainty. Moreover, the opportunity costs of these alternatives will be subjective and unique to the individual extractive firm. In fact, for the extractive firm choosing one of these strategies, the opportunity costs will necessarily include a subjective reckoning of the entrepreneurial income thought to be obtainable from the next most profitable relinquished strategy (Buchanan 1969, 49–50).

A few additional words of clarification may be worthwhile with respect to these options. First, in terms of maintaining entrepreneurial income, one may be tempted to conclude that the second strategy would be pursued rather than the first because the second does not entail the uncertainty and cost that would necessarily be involved with finding new resources. However, firms engaged in extraction are always in search of new and more profitable deposits to replace depleting extractive-resource deposits. In choosing a capital-maintenance strategy, the extractive firm compares the marginal expected opportunity cost of finding, developing, and exploiting new deposits with the marginal expected opportunity cost of developing and extracting an existing known deposit. If the former costs are less that the latter, a decision to find new deposits promises a greater yield of entrepreneurial income.

14. An exploratory effort can be viewed as successful if the firm making the discovery considers it to be a realistic candidate for eventual development and production.

The third strategy is very common in the petroleum industry and may entail the outright purchase of an existing extractive operation from another firm. The extractive firm would be inclined to pursue this strategy if the quality (lower cost) of the deposits available for purchase were superior to those already under the firm's immediate control. An important aspect of this third strategy is that it reflects a decision to deliberately delay exploration or development of the property and resources to which the extracting firm already has access on existing leases. In other words, the firm would be exercising speculative latitude in the timing of the exploration or development on its existing leases. The fourth strategy is probably a less-common occurrence *unless* some additional delineation drilling were undertaken by the discovering firm to provide additional information on the minimum volume of the resource discovered.[15] Again, as in the case of the third strategy, the fourth strategy may reflect a decision to exercise speculative delay with respect to prospects on leases already under the firm's control. Deposits already under the firm's control may be low-quality, high-cost properties for which delay may well be the best course of action.

The fifth strategy is commonly premised on an expectation that the capital value of a project will be greater if it is delayed until a later time. Although such deliberate delay may be based on expectations of longer-term rising trends in the price of the resources itself, it may also reflect the extractive enterprise's efforts to manage the costs of a prospective project. Delay may enhance the extractive enterprise's income by lowering the opportunity costs associated with the respective stages of investment in a planned project. In particular, such delay may be helpful in avoiding cost increases from bottlenecks that are likely to be encountered in efforts to expedite exploration and development.[16] In the context of capital maintenance by the extractive firm, any reduction in cost may significantly enhance prospective entrepreneurial income. Again, however, such delaying actions in a disequilibrium setting will be undertaken strictly on the basis of entrepreneurial judgments.

But an extractive enterprise may choose the fifth strategy, delay, for reasons that bear largely on volatility in the resource's price. The different stages of the production process accord ownership of successive series of capital goods, each of which represents a type of investment "option." Ownership of any investment option represents a right but not an obligation to proceed further with the next opportunity in a sequence of investment opportunities. In this case, the sequence of capital goods includes *(a)* exploration rights for particular lands, *(b)* discovered resources, *(c)* de-

15. This additional expense would involve what mineral engineers refer to as "delineation drilling."

16. This insight applies to production in general; see Alchian 1959, 23–40. Alchian's observation is borne out in the research on leasing of federal offshore lands on the Outer Continental Shelf; Walter Mead and his colleagues note: "If development of the resource is required in a short period of time, bottlenecks would surely develop in acquiring the skilled labor and specialized capital equipment. . . . [B]y allowing more time for lease development, the labor and capital equipment markets can respond to increased demand for these inputs with increased production at prices lower than those that would prevail under more pressing time constraints" (1985, 110–12).

veloped resources, and *(d)* extracted resources ready to be sold. Each of these capital goods has a market value. Volatility of the resource's price will be reflected in volatility of the market worth of each of these capital goods. Greater volatility of the resource's price enhances the market value of each of these four capital goods, but this increase in value is contingent on the extractive firm's ability to delay action on each succeeding phase of investment. For example, in undertaking investment in exploration, the capital good sought is discovered resources. These discovered but undeveloped resources are marketable and have a price, but they also represent an option to acquire developed resources. In the commitment to subsequent investment in development, the capital goods sought are developed resources. At each successive stage, the extractive firm will find it advantageous to delay any further commitment to the project until changing market conditions reveal more information about the future and the potential profitability of the next investment option.[17] This advantage is reflected in an enhanced market value of each of the capital goods and of the extraction project as a whole (Dixit and Pindyck 1994, 4; Cowen 1997, 26). Hence, decisions to delay bear directly on prospective entrepreneurial income and are critical in maintaining the extractive firm's capital value.

The sixth strategy emphasizes the point that capital maintenance for all entrepreneurial enterprises requires investment in the capital goods that offer the greatest likelihood of attaining or maintaining profitability. The strategy highlights the reason that cost minimization in the replacement of physical capital goods is not necessarily equivalent to capital maintenance. The real motivation for investment to maintain capital is not to minimize the cost of replacing particular capital goods, but to increase income (Hayek [1941] 2007, 277–78). In the case of the sixth strategy, the two may be quite different because "cost" minimization (or expense minimization) does not take into account the returns to investment in capital goods that may not be directly related to the firm's historical specialization.

Such a shift in the physical composition of capital goods sought in capital maintenance may be prompted by newly revealed changes or previously unrecognized entrepreneurial opportunities in other markets. Hayek captures the entrepreneurial motivations for such shifts in investment: "[W]hen we proceed to consider in detail the reaction of capitalists to unforeseen changes, . . . as soon as we go back to the *rationale* of maintaining capital intact, the quantity of capital drops right out of the picture as a directly relevant magnitude. Its place is taken by a direct consideration of the size of the income streams that may be expected at different dates" ([1941] 2007, 280), emphasis in original). It is in this sense that Adelman's focus on the physical replacement of resource deposits conveys a misleading interpretation of the investments necessary to maintain capital for the extractive firm. The converse of these observations is that investment by all firms, inside or outside of the extractive indus-

17. Each successive stage of investment in the project imparts a successively higher market price to the project itself because these properties are traded between firms.

tries, is sensitive to any anticipated higher returns that may be achievable as a consequence of anticipated scarcities of particular extractive resources.

The extractive firm may be constrained in its choice of replacement investments by realities of capital-good complementarity. An extractive enterprise's grouping of capital goods normally takes the form of resource deposits or assets related to the extractive activity, such as processing or transportation, but if the enterprise were to invest in capital goods not necessarily related to extraction, it would be mindful of the degree to which such capital goods complement the assets that compose its existing operations. The most important issue, however, would not necessarily pertain to the physical complementarity of capital goods. The central concern is the extent to which the particular investment alternative promises the largest addition to entrepreneurial income for the enterprise as a whole. For any particular future investment that the extractive firm may consider, replacement of resource deposits may or may not be the best means to attain the objective of higher profitability. Expected profitability always establishes *economic* complementarity, and, to the extent that anticipated income is sufficiently high, it supersedes issues that may bear on the physical complementarity of capital goods already within the enterprise.

Institutions and Policies that Impede Capital Maintenance for Extractive Firms

Although capital maintenance by extractive firms refutes the exhaustion myth, this refutation hinges on access to lands, entrepreneurial latitude in managing resources, and secure private-property rights. But certain institutions of governmental control and jurisprudence hinder entrepreneurial actions of extractive firms striving to maintain capital. These hindrances include: *(a)* foreclosure of land access by government ownership of mineral lands; *(b)* foreclosure of entrepreneurial latitude by court-imposed covenants enforcing obligations to surface owners; and *(c)* in the case of petroleum, the extractive firm's inability to acquire full control and ownership of reservoirs it has discovered. The first of these impediments bears on access to land, and the latter two impede extractive firms' ability to manage resource deposits as capital assets.

Foreclosure of Land Access by Government Ownership

Maintenance of entrepreneurial income requires the replacement of the capital goods critical to continued operation in the same industry. This entrepreneurial process requires that the firm have access to new resources that may be extractible at lower cost. Resource replacement usually depends on leasing arrangements between surface owners and entrepreneurial firms that seek to find and develop new deposits. Through an unhampered market process, resources tend to gravitate to their highest valued

use. The one obstacle facing the entrepreneurial extractive firm in its efforts to maintain capital is that some properties are controlled by landowners who can totally foreclose access rights to extractive firms. These owners are invariably governments that have merely nationalized lands through acts of political power without any actions establishing legitimate ownership. Once these lands are under governments' political control, access is established through a political process. In modern democracies, this conflict is manifested in political struggles to marshal the power of legislatures to assure certain politically popular uses of lands and to foreclose less-popular uses.

This political selection of popular uses of nationalized lands is one of the more pernicious features of democratic processes. Once lands are nationalized, alternative uses of them are chosen with the intent of appeasing "stakeholders." For the purposes of this inquiry, the important question is: Who is a stakeholder with respect to the use of public lands? Unfortunately, political self-selection is the only criterion used to establish who has a legitimate stake in decisions about the alternative uses of government lands. Stakeholders are voters with diverse and subjective views about what constitutes an environmental amenity for them and how its presence or absence affects them. This political process takes the focus off legitimate environmental issues and instead motivates allocative decisions on the basis of the placation of certain self-selected political constituencies (Brätland 2004, 528–32). This participatory process has little to do with rational environmental policy or with the commitment of resources to their highest-valued use.

Political advocates of policies that foreclose access are unencumbered by the opportunity costs of such sanctions. In this sense, forsaking the value of the next most highly valued opportunity never impinges on the actions of nonowning bureaucrats, politicians, or environmentalists who seek to foreclose certain uses of government lands. Problems of resource exhaustion and firms' failure to replace resource deposits can arise because the weighing of opportunity costs plays virtually no role in foreclosing lands to exploration and development. In bearing little of the opportunity costs of political foreclosure of access, self-selected stakeholders have incentives to become extremists in exaggerating preferences and overstating claims. Whatever the benefits of foreclosing exploration and development may be, these benefits are provided as a free good through the process of political control.

Foreclosure of Entrepreneurial Latitude by Obligations to Surface Owners

As argued earlier, the extractive firm must have ample timing latitude if its efforts to replace resources are to succeed. However, an early juridical declaration of surface-owner rights has tended to preclude this speculative latitude in maintaining capital. The British jurist William Blackstone first enunciated an interpretation of the land

surface owner's rights to subsurface minerals: "land hath also, in its legal specification, an indefinite extent, upwards as well as downwards . . . downwards, whatever is in direct line between the surface of any land and the center of the earth . . . if a man grants all his lands, he thereby grants all mines of metal and other fossils. This is incorporated in the fundamental law of the land" ([1766] 1983, 18).

The modern-day implication of this interpretation of the surface owner's rights is that the surface owner is entitled to a fixed percentage royalty on the gross proceeds from the sale of the extracted mineral.[18] Under this entitlement, the surface owner and the extractive enterprise that has acquired a lease have mutually and fundamentally incompatible objectives. Because of uncertainty and economic change, speculative latitude is always critical in managing capital goods, including mineral leases. The management of mineral leases as capital goods requires that lease activities be scheduled so that the capital value of entrepreneurial income is maximized. However, given the fixed-percentage royalty on gross proceeds to which the surface owner is entitled, speculative timing decisions by lessees almost always diminish the present value of royalty income. The surface owner prefers that the extraction operation be managed so that royalty revenue is captured as quickly as possible (Brätland 2001, 694–95).[19]

In sum, speculative timing of production by the royalty-paying lessee is critical to the maintenance of capital but anathema to the surface owner's interests. Moreover, the surface owner's financial rights are protected by court-imposed implied covenants that foreclose any action or lack of action that delays or diminishes the surface owner's receipt of royalties. By curtailing speculative latitude in the timing of production, the covenants reduce the net present value of mineral resources and impede the extractive enterprise's ability to maintain capital.

Special Circumstances of Petroleum and the Issue of Owning Discoveries

Blackstone's declaration of surface-ownership rights presents difficulties in its application to in situ petroleum, given the unusual characteristics of petroleum deposits. Because of petroleum's migratory nature, the resource can often be extracted from the reservoir beneath the land of several different surface owners. Hence, a rule of capture has evolved such that a discovered reservoir never becomes a capital good to be managed by the entrepreneurial firm. The rule of capture applies even though the petroleum being extracted may have migrated from beneath another surface owner's property.

18. The surface owner is usually also the owner of royalties; however, situations exist in which royalty streams are sold as investment assets. In other instances, the surface owner's property rights may not include mineral rights, in which case presumptive royalty obligations are owed to the owner of those rights.

19. In the context of the petroleum lease, the surface owner's economic interests are defined by the attainment of a rate of revenue recovery that maximizes the present value of the royalty-receivables revenue stream. Delay only diminishes this present value. Hence, expedited recovery of royalty revenue is always optimal for the surface owner as a lessor.

Application of Blackstonian principles has not specified that the owner of the surface also necessarily owns subsurface petroleum, but that owner is always entitled to a percentage share of gross production or a percentage share of the gross sales proceeds of production. Again, to this end, the courts have imposed the covenants mentioned previously to protect the surface owners' financial interests. The consequence of the covenants is that the royalty-owning surface owner essentially precludes the management of petroleum leases as capital assets. In so doing, the implied covenants dissipate entrepreneurial income by compelling exploration, development, and production on expedited schedules that may be inconsistent with the efficient management of extractive operations. Moreover, mandates to undertake these activities at an earlier time entails that in almost all cases the opportunity cost associated with these activities will be increased (Mead et al. 1985, 110–12). In circumstances unimpeded by the covenants, a decision to expedite exploration or development would be made only if doing so was expected to increase the project's capital value. Attempts to impose artificial schedules on decision makers can only create confusion, chaos, and impediments to the maintenance of capital.

The conflict, ethical breeches, and implied covenants associated with current property law would not exist if the discovered petroleum deposit were to become the sole, exclusive property of the extractive enterprise making the discovery. In this case, ethically and functionally legitimate ownership would be achieved by applying the principle of original appropriation and by discarding the Blackstonian strictures on the scope of the surface owner's property rights.[20] Of course, in this situation, some consent to surface access would still be required from a surface owner to make exploration possible.[21] Court-imposed covenants would no longer impinge on the discovering firm's ability to engage in speculative timing in the scheduling of investments in the project. In this case, the surface owner would have no contingent claim on production. This situation would represent the normative ideal from both an allocative and an ethical perspective.

Concluding Comments

The myth of resource exhaustion has persisted from the nineteenth century to the present. It has been discernable in the work of different economists ranging from the neoclassical to the Austrian to the institutionalist. In the neoclassical school, the myth has arisen from a reliance on equilibrium assumptions and from an imagined global exhaustion of resource stocks. Hence, this school has, with very few notable excep-

20. This proposal was first put forward by Murray Rothbard ([1982] 1998, 71–72). Robert Bradley has advanced a version of the Rothbard proposal (1996, 69–74).

21. In most cases, a single surface owner would not be able to extort a royalty concession from an exploring entrepreneur who is establishing ownership of a subsurface discovery. Directional drilling would be permitted so that a particular subsurface structure could be accessed from a multiplicity of surface locations. Competition between surface owners would weaken any single surface owner's bargaining power.

tions, failed to recognize that resource deposits are replaceable capital goods. In the case of the Austrian school, the myth is evident in one instance in an apparent focus on the depletion of aggregate stocks and a surprising categorization of resource deposits as nonaugmentable *land* rather than as replaceable capital goods. Erich Zimmermann, a representative of the institutionalists, emphasized that entrepreneurship and scientific advance tend to ameliorate concerns about resource availability. His work, however, is marred by a disdain for certain market institutions that are critical for resource availability and further flawed by his neglect of the firm as an institution vital to the replacement of depreciable capital goods, such as resource deposits.

Refutation of the exhaustion myth must be grounded in an understanding of capital maintenance as the entrepreneurial firm's strategy for maintaining the equity value or resources committed to a particular business plan. Entrepreneurial resource replacement is one example of capital maintenance for the extractive enterprise. It occurs routinely because gradual depletion of deposits reduces the operating margins of the extractive enterprise. Because capital maintenance is always aimed at the maintenance of enterprise income, the firm is constantly replacing its depleting resource deposits through acquisition of exploration rights, discovery, and development of new deposits, but it focuses on maintaining capital, not necessarily on replacing particular capital goods. Hence, in some cases, capital maintenance may be served best by investment in capital goods not necessarily related to the extraction of resources. Replacement of resource deposits depends on the prospective profitability of doing so; therefore, anticipated shortages of extractive resources are a principal inducement of deposit replacement. The means by which resources are replaced emerges out of the entrepreneur's judgment of how alternative prospective replacement strategies affect enterprise income.

The resource-replacement process is fundamentally entrepreneurial and depends on access to land and on managerial flexibility in maintaining capital and entrepreneurial income. Entrepreneurial capital maintenance as applied to replacement of resource deposits is impeded by three institutions: (1) direct or indirect nationalization of much or most of the mineral-bearing land around the world; (2) regulatory sanctions imposed by the courts to protect the surface owner's presumptive rights to a portion of the minerals produced or of the proceeds from extraction and sale of these minerals; and (3) in the case of petroleum, the extractive firm's inability to acquire full ownership and control of reservoirs that it has discovered. A property rule in which discoverers obtain unencumbered ownership of discovered reservoirs would solve the latter longstanding problem.

References

Adelman, Morris. 1993. *The Economics of Petroleum Supply.* Cambridge, Mass.: MIT Press.

———. 1995. *Genie Out of the Bottle.* Cambridge, Mass.: MIT Press.

Alchian, Armen. 1959. Costs and Output. In *The Allocation of Economic Resources,* edited by Moses Abramovitz, 23–40. Stanford, Calif.: Stanford University Press.

Blackstone, William. [1766] 1983. *Commentaries on the Laws of England*. Vol. 2. Special ed. New York: Legal Classics Library.

Bradley, Robert L. 1996. *Oil, Gas, and Government: The U.S. Experience*. Lanham, Md.: Rowan and Littlefield.

———. 2007. Resourceship: An Austrian Theory of Mineral Resources. *Review of Austrian Economics* 20, no. 1: 63–90.

Brätland, John. 2000. Human Action and Socially Optimal Conservation: A Misesian Inquiry into the Hotelling Principle. *Quarterly Journal of Austrian Economics* 3, no. 1: 3–26.

———. 2001. Economic Exchange as the Requisite Basis for Royalty Ownership of Value Added in Natural Gas Sales. *Natural Resources Journal* 41, no. 3: 685–711.

———. 2004. Externalities, Conflict, and Offshore Lands: Resolution Through the Institutions of Private Property. *The Independent Review* 8, no. 4 (spring): 527–48.

———. 2006. Toward a Calculational Theory and Policy of Intergenerational Sustainability. *Quarterly Journal of Austrian Economics* 9, no. 2: 13–45.

Buchanan, James M. 1969. *Cost and Choice: An Inquiry in Economic Theory*. Chicago: Markham.

Cowen, Tyler. 1997. *Risk and Business Cycles: New and Old Austrian Perspectives*. New York: Routledge.

Dixit, Avinash, and Robert Pindyck. 1994. *Investment under Uncertainty*. Princeton, N.J.: Princeton University Press.

Gray, Lewis C. [1914] 1967. Rent under the Assumption of Exhaustibility. *Quarterly Journal of Economics* (May); reprinted in *Extractive Resources and Taxation,* edited by Mason Gaffney, 423–46. Madison: University of Wisconsin Press.

Hartwick, John M. 1977. Intergenerational Equity and Investing of Rents from Exhaustible Resources. *American Economic Review* 67, no. 4: 972–74.

———. 2000. *National Accounting and Capital*. Cheltenham, U.K.: Edward Elgar.

Hayek, F. A.. [1941] 2007. *The Pure Theory of Capital*. Chicago: University of Chicago Press.

Heal, Geoffrey. 1998. *Valuing the Future: Economic Theory and Sustainability*. New York: Columbia University Press.

Hotelling, Harold. 1931. The Economics of Exhaustible Resources. *Journal of Political Economy* 39: 137–75.

Jevons, W. Stanley. 1865. *The Coal Question: An Inquiry Concerning the Progress of the Nation and the Probable Exhaustion of Our Coal Mines*. London: Macmillan.

Kirzner, Israel. 1996. *Essays on Capital and Interest: An Austrian Perspective*. Cheltenham, U.K.: Edward Elgar.

Lachmann, Ludwig. 1986. *The Market as an Economic Process*. New York: Basil Blackwell.

Lewin, Peter. 1999. *Capital in Disequilibrium: The Role of Capital in a Changing World*. London: Routledge.

Lewin, Peter, and Steven E. Phelan. 2000. An Austrian Theory of the Firm. *Review of Austrian Economics* 13: 59–79.

McDonald, Stephen. 1967. Percentage Depletion, Expensing Intangibles, and Petroleum Con-

servation. In *Extractive Resources and Taxation,* edited by Mason Gaffney, 269–88. Madison: University of Wisconsin Press.

———. 1971. *Petroleum Conservation in the United States: An Economic Analysis.* Baltimore: Johns Hopkins University Press.

Mead, Walter, Asbjorn Moseidjord, Dennis Muroaka, and Phillip Sorensen. 1985. *Offshore Land: Oil and Gas Leasing and Conservation on the Outer Continental Shelf.* San Francisco: Pacific Institute for Public Policy Research.

Mises, Ludwig von. [1949] 1998. *Human Action: A Treatise on Economics, The Scholar's Edition.* Auburn, Ala.: Ludwig von Mises Institute.

———. [1962] 2006. *The Ultimate Foundations of Economic Science.* Indianapolis, Ind.: Liberty Fund.

Morse, Chandler. 1976. Depletion, Exhaustibility, and Conservation. In *Economics of the Mineral Industries,* edited by William Vogely, 224–70. New York: American Institute of Mining Metallurgical and Petroleum Engineers.

National Research Council. 1999. *Nature's Numbers: National Economic Accounts to Include the Environment.* Washington, D.C.: National Academy Press.

Random House Dictionary of the English Language, unabridged ed. 1969. New York: Random House.

Rothbard, Murray N. [1982] 1998. *The Ethics of Liberty.* New York: New York University Press.

———. 2004. *Man, Economy, and State, with Power and Market.* Auburn, Ala.: Ludwig von Mises Institute.

———. [1973] 2006. *For a New Liberty: The Libertarian Manifesto.* Auburn, Ala.: Ludwig von Mises Institute.

Solow, Robert. 1986. On the Intergenerational Allocation of Natural Resources. *Scandinavian Journal of Economics* 88: 141–49.

Zimmermann, Erich. [1933] 1951. *World Resources Industries: A Functional Appraisal of the Availability of Agricultural and Industrial Materials.* New York: Harper and Row.

———. 1957. *Conservation in the Production of Petroleum: A Study in Industrial Control.* New Haven, Conn.: Yale University Press.

Acknowledgments: The views expressed in this article are strictly those of the author. A version of this paper was presented at the annual meeting of the Society for the Development of Austrian Economics in Charleston, South Carolina, November 18–21, 2006. The author thanks Peter Lewin for his thoughtful remarks on the article.