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Economic Indicators of Resource Scarcity: A Critical Essay*

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The theoretical arguments of the conceptual and empirical literature on economic indicators of long run resource scarcity are logically flawed. If resource allocators were informed of the nature of resource scarcity, their behavior and the economic indicators it generates would reflect the scarcity. But if they were so informed, we could simply ask them if resources were scarce. If they are not informed, their behavior and economic indicators are as likely to indicate their ignorance as the reality. Unfortunately, there is no way of knowing whether they are informed or not unless we already know whether resources are scarce.

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1. INTRODUCTION

During the past quarter century, natural resource economists have developed an extensive literature on the theoretical advantages and disadvantages of alternative indicators of long-run natural resource scarcity. Detailed empirical analyses have been undertaken. The conceptual elaborations and discussions of the empirical findings are well elaborated in textbooks on resource economics. Both the conceptual arguments and findings have been used to justify *laissez faire* with respect to resources in other economic literatures and beyond. I argue that the logic behind the arguments that economic indicators can inform us of whether resources are scarce or not is fallacious.

In Section 2 I review the literature on resource scarcity. I clearly distinguish between the "theoretical" literature which deduces resource cost and price paths under different assumptions about resource scarcity and the "empirical" or indicator literature which tries to deduce from cost and price paths whether resources are in fact scarce. I conclude that our understanding of the possible cost and price paths and the sensitivity of these paths to new conditions has been so enriched by the past decade of theoretical explorations that our only somewhat earlier conceptual discussions about scarcity indicators and the empirical attempts to deduce whether resources are scarce now seem naive. This conclusion, however, is merely background, an observation on the state of our knowledge.

In Section 3, I identify the following logical fallacy. Economic indicators of long-run scarcity are rooted in the models of Ricardo or Hotelling which assume that resources are scarce, assume that resource allocations are informed of the scarcity, and then deduce cost and price paths. If resource allocators are not

*Richard Howarth, numerous other students and colleagues, ten journal reviewers, and one understanding editor have assisted me in the exposition of this argument.

informed, the cost and price paths their decisions generate are as likely to reflect their ignorance as reality. To control for whether or not allocators are informed, however, we would have to know whether resources are scarce. Since this is the original question, the exercise is logically impossible.

In Section 4, I ponder how this fallacy was overlooked in light of the significant earlier literature in which economists argued that resources have not been exploited in the manner indicated by the model of Ricardo. In Section 5, I present a brief philosophical conclusion.

2. A REVIEW OF THE LITERATURE

Barnett and Morse [4] argued in 1963 that the long-run scarcity of natural resources can best be assessed by looking at economic indicators. Changes in the physical quality and availability of resources, they argued, are inadequate for they do not account for the past effects of and future potential for technological change and substitution. Following Ricardo [25], they analyzed changes in the quantity of labor and capital needed to extract a unit of resource and tested whether extraction technologies and new opportunities for substitution were outpacing declines in the physical qualities of resources. For an aggregate of all natural resources, this indicator decreased from 210 in the latter part of the 19th century to 47 in the middle of the 20th. This fourfold decline in the difficulty of accessing resources has frequently been juxtaposed in the popular economic literature [27] to the concerns of natural scientists and the public about the physical limits to growth.

Since this seminal work, numerous resource economists have debated the merits of other indicators of resource scarcity, principally total extraction costs, royalties, prices, and elasticities of substitution. Empirical analyses have been updated, better data have been utilized, superior econometric techniques have been used, the trends of different indicators have been compared, and hypotheses about turning points in trends have been tested [15, 28]. The energy crisis and its impacts on the costs of extracting other resources have left the profession much less sanguine about long run resource availability. Nevertheless, in this now apparently mature area of research, the superiority of economic indicators of scarcity remains a basic premise. Let me refer to this body of work as the “empirical literature.”

There is a second, closely related, literature in resource economics. Since the energy crisis, economists have elaborated on Hotelling’s [18] model of efficient resource extraction. This literature has explored how extraction costs, royalties, and prices are affected over time by the size of the resource stock, interest rates, market structure, taxation policies, and substitute technologies. This second literature has more recently given special attention to how the paths of costs, royalties, and prices depend upon the quality of information used by resource allocators [31]. By exploring alternative combinations of the above factors, we now know that prices and royalties can behave in a wide variety of ways. Furthermore, changes in any of the factors during the period reset the path and produce discontinuities. Given the multiple changes in the factors and lagged responses that occur in reality, the initial conception in this literature of a “path” has become moot [1] for

other than pedagogic purposes. Let me refer to the work elaborating the Hotelling model as the “theoretical literature.”

There has been some interplay between the literatures. Curiously, however, the very factors whose exploration has made the theoretical literature so voluminous are ignored in the empirical literature. The empiricists have presumed that they can identify whether resources are scarce from economic indicators without controlling for the same factors that the theoretical literature has shown can make the indicators follow very different patterns.

Scarcity analysts, for example, have given considerable attention to the effects of the change in the structure of petroleum markets at the time of the energy crisis [15]. Hotelling, however, also explored the effects of different interest rates, contemplated both taxes and depletion allowances, and considered the impacts of petroleum regulation [18, p. 138 and pp. 143–144]. Each of these has changed dramatically over time and has had a major effect on the petroleum industry. Each has been explored quite thoroughly in the theoretical literature [6, 8, 16, 22]. But these key factors have not been included as variables in the empirical literature on resource scarcity. The imposition of and changes in oil import controls [21] and natural gas price regulation [24] also influenced industry behavior during this same period. The numerous factors that have been considered in the theoretical literature have not been controlled for in the empirical literature.

The superiority of analyzing economic indicators to assess resource scarcity dissolves when we consider the difficulty of determining all of the effects of changes in these numerous factors on economic indicators and distinguishing these effects from those of scarcity. No one has successfully used theory to describe the history of costs, royalties, and prices for any resource industry. If theory has not been used effectively to describe the history of basic economic indicators for one industry, it is inconceivable that it can be invoked to explain whether resources are becoming more scarce by looking at *changes* in the indicators over *aggregates* of resource industries. Thus with the considerable benefit of hindsight, the conceptual discussions and empirical analyses of economic indicators of resource scarcity now appear naive.

3. THE LOGICAL FALLACY

The recent theoretical advances, however, are not key to identifying a logical flaw in the literature on economic indicators of long run resource scarcity.

In the Ricardian model, resource allocators have to know which resources are of higher quality so that they can be used first. The Hotelling model assumes resource allocators are aware of far more: the total stock of resources, the course of technological development, and the level of demand throughout the future. These far stricter information requirements give royalties the property of “looking ahead” [5]. The importance of these information assumptions has been thoroughly explored in the theoretical literature. Solow [30] and Dasgupta and Heal [10] explored the implications of the fact that knowledge both of the total resource stock and of future demand and technologies is necessary for the model to have a stable equilibrium. The theoretical literature contains numerous articles which explore variations on the information assumptions of the model [2, 30].

Both Ricardo's and Hotelling's theoretical models can be reduced to the following simple syllogism:

Major Premise: If resources are scarce, and

Minor Premise: If resource allocators are informed of resource scarcity,

Conclusion: Then economic indicators will reflect this scarcity.

The studies in the empirical literature on scarcity have run this argument backwards, trying to determine whether resources are scarce, the major premise of the initial theoretical syllogism, by looking at resource indicators, the conclusion of the initial theoretical syllogism.

Those who have contributed to the conceptual literature on indicators and those who have undertaken empirical analyses have ignored the minor premise. Barnett and Morse, for example, argued that their findings refuted the predictions of Ricardo, hence refuted the assumption of scarcity. But it is not clear that their findings do not simply refute the assumption of informed allocators.

Authors contributing to the theoretical elaboration of the Hotelling model have always made their assumptions with respect to information explicit. But I have not found a single reference to the relationship between the nature of the information known to resource allocators and the interpretation of the cost or price path in the literature on economic indicators of resource scarcity. The results of the empirical analyses have been interpreted in publications for the economics profession as a whole and for the public at large without these relations being made explicit. It appears, furthermore, that resource economists themselves have not made the connections between the findings in the theoretical literature with respect to the knowledge of allocators and the interpretation of economic indicators. Even the innovative effort of Devarajan and Fisher [13] linking willingness to explore for resources to the value of resources *in situ*, and hence the value of royalties commits the same logical fallacy. Though it addresses a lack of information associated with the future and the uncertainties of exploration, it explicitly assumes that ores are exploited systematically by grade and that only the next best grade of resources are treated as exploration discoveries, as if explorers never come across superior grades.

Models are necessarily simplifications of reality and most empirical work can be improved with better data. Thus numerous economists on reading the foregoing critique have argued that identifying deficiencies is relatively easy and that real contributions to economics both identify and work towards the correction of the problem. If a proper analysis must control for whether resource allocators are informed, then an empirical study should be undertaken which includes such a control. Only by including and controlling for this factor will we discover whether the deficiency is significant or not.

But to control for whether allocators are informed of resource scarcity would require prior knowledge on the part of the analyst as to whether resources are scarce or not, the very question the analyst is pursuing in the first place. Thus I have not simply identified a deficiency in the model or the data. I have identified a logical fallacy.

Logical fallacies typically have diverse and entertaining twists. There is something especially ironic about the search for information about the scarcity of resources through models which assume economic actors are informed of the

scarcity of resources. Why scarcity empiricists thought they could determine more about the natural world by analyzing allocators' actions than allocators already knew at the time they acted has amused natural scientists for some time [9, 14, 23]. If we truly believed we could use neoclassical theory to interpret whether resources were scarce, we would be confident that resource allocators were informed, that they were acting as rationally as theory assumes they do, and hence that resources were being allocated efficiently over time. In such a world, analysts could simply ask allocators whether resources were scarce. The answer might still encourage society to reallocate resource rights over generations [19], but efficiency would not be an issue. Quite simply, if the conditions necessary for the economic analysis of scarcity existed, there would be much less reason to undertake economic analyses of scarcity.

The identification of logical fallacies can also lead to constructive insights. It seems reasonable in retrospect that one cannot expect economic indicators to contain more information than the economic actors had at the time they generated them. This suggests that rather than waiting a decade or two for allocators to generate a time series of economic indicators to analyze, it would be more reasonable to ask them directly what they know about scarcity and receive their latest understanding. This argument is especially true when allocators are only partially informed, for the indicators which result from their behavior are likely to be even more difficult to interpret.

4. HOW DID WE GO WRONG?

Though Hotelling presented his now famous model three decades before Barnett and Morse published their classic analysis, very few economists read Hotelling until yet another decade later. Thus the many insights in Hotelling were not really available to Barnett and Morse. The scarcity empiricists of the later 1970s, however, did have access to Hotelling and a burgeoning literature interpreting and elaborating on his model. Though the arguments for looking at royalties and eventually for looking at prices themselves arose with the rediscovery of Hotelling, those in search of economic indicators somehow suppressed both the stringencies of the assumptions underlying Hotelling's model and the sensitivity of the price paths to changes in any one of numerous factors. The review of the theoretical literature by Devarajan and Fisher on the fiftieth anniversary of Hotelling's original article [12], for example, clearly noted how price paths shifted discontinuously in response to numerous different types of changes but failed to provide an interpretation of what this meant for real price paths where changes are constantly occurring.

Even Barnett and Morse, however, should have been more sensitive to what might be referred to as the "Mayflower Problem." If the Pilgrims knew where the best places for an agricultural colony were, they would not have gone to Plymouth Rock. The history of North America, the focus of all of the empirical studies to date, is a history of using low quality resources before learning led to the exploitation of higher quality, less costly resources. Many generations passed before American agriculture shifted from the relatively poor soils of the east coast to the more productive midwest.

Economists have long argued that Ricardo's model, and implicitly Hotelling's, did not fit history. Carey [7] argued that Ricardo's model did not fit the development of agriculture in the United States. Barger and Schurr [3] argued that resources were not a constraint on increasing output in the mineral industries. They noted how petroleum production in the United States progressed from fields in Appalachia which were difficult to exploit and not very productive to the salt domes of the south and then to the East Texas field which were easier to exploit and far more productive. Prudhoe Bay, not discovered until 1968, is even less expensive to exploit though the costs of transport are high. Oris Herfindahl [17] argued that mineral prices reflected marginal costs of production unaffected by perceptions of future value. Neither Kendrick [20] nor Denison [11] investigated changes in resource quality in their accountings of economic growth, arguing that farmers and miners had not exploited the best resources first.

Barnett and Morse referenced Carey but interpreted his argument as a critique of whether resources were scarce rather than as a critique of whether Ricardo's model fit history. Other economists also pondered the earlier literature [29]. Nevertheless, scarcity empiricists never seriously considered the fact that economists had long noted that our theoretical models do not readily explain economic history with respect to the most basic patterns and hence are not likely to be useful for pursuing the more difficult question as to whether or not resources are scarce.

5. CONCLUSION

The variance in interpretations by philosophers as to what constitutes science and how it works has increased dramatically during the past quarter century. The once dominant idea that knowledge can be objective, that it systematically accumulates, and that it will ultimately merge to a consistent whole now competes with various ideas about the nature of subjectivity, the inevitability of some aspects of relativity, shifting domains of emphasis in knowledge, and incommensurabilities between patterns of thinking [26]. Yet two beliefs about science have not significantly changed: (1) science feeds on the tension between theory and reality, and (2) individual scientific arguments must be logical. The attempt to use economic indicators to determine whether resources are scarce over the long run has not met either of these criteria of what makes an endeavor scientific.

REFERENCES

1. T. D. Agbeyegbe, Interest rates and metal price movements: Further evidence, *J. Environ. Econom. Management* **16**, 184–192 (1989).
2. K. Arrow and S. Chang, Optimal pricing, use, and exploration of uncertain natural resources stocks, *J. Environ. Econom. Management* **9**, 1–10 (1982).
3. H. Barger and S. Schurr, "The Mining Industries, 1899–1939: A Study of Output, Employment, and Productivity," Nat. Bur. Econom. Res., New York (1944).
4. H. Barnett and C. Morse, "Scarcity and Growth: The Economics of Natural Resource Availability," Johns Hopkins Press, Baltimore (1963).
5. G. M. Brown and B. C. Field, Implications of alternative measures of natural resource scarcity, *J. Polit. Economy* **86**, 229–243 (1978).
6. H. Burness, On the taxation of nonreplenishable natural resources, *J. Environ. Econom. Management* **3**, 289–311 (1976).

7. H. Carey, "Principles of Political Economy, The Past, Present, and Future," Carey, Lea & Blanchard, London (1837).
8. R. F. Conrad and B. Hool, Resource taxation with heterogenous quality and endogenous reserves, *J. Public Econom.* **16**, 17–33 (1981).
9. E. Cook, Limits to exploitation of nonrenewable resources, *Science* **191**, 677–682 (1976).
10. P. S. Dasgupta and G. M. Heal, "Economic Theory of Exhaustible Resources," Cambridge Univ. Press, Cambridge, UK (1979).
11. E. F. Denison, "The Sources of Economic Growth in the United States and the Alternatives Before Us," Committee for Economic Development, New York (1962).
12. S. Devarajan and A. C. Fisher, Hotelling's "Economics of Exhaustible Resources": Fifty years later, *J. Econom. Lit.* **19**(1):65–73 (1981).
13. S. Devarajan and A. C. Fisher, Exploration and scarcity, *J. Polit. Economy* **90**:1279–1290 (1982).
14. P. R. Ehrlich, The limits to substitution: Meta-resource depletion and a new economic–ecological paradigm, *Ecological Econom.* **1**, 9–16 (1989).
15. D. C. Hall and J. V. Hall, Concepts and measures of natural resource scarcity with a summary of recent trends, *J. Environ. Econom. Management* **11**, 363–379 (1984).
16. T. Heaps, The taxation of nonreplenishable natural resources revisited, *J. Environ. Econom. Management* **12**, 14–27 (1985).
17. O. Herfindahl, "Three Studies in Mineral Economics," Resources for the Future, Washington, D. C. (1961).
18. H. Hotelling, The economics of exhaustible resources, *J. Polit. Economy* **39**, 137–175 (1931).
19. R. B. Howarth and R. B. Norgaard, Intergenerational resource rights, efficiency, and social optimality, *Land Econom.* **66**, 1–11 (1990).
20. J. W. Kendrick, "Productivity Trends in the United States," Nat. Bur. Econom. Res., New York (1961).
21. W. F. Lovejoy, Oil import policies as they relate to national security, *Quart. Colorado School of Mines* **64**, 157–180 (1969).
22. W. F. Lovejoy and P. T. Homan, "Economic Aspects of Oil Conservation Regulation," Johns Hopkins Press, Baltimore (1967).
23. D. B. Luten, Ecological optimism in the social sciences: The question of limits to growth, *Amer. Behav. Scientist* **24**, 125–151 (1980).
24. P. W. MacAvoy and R. S. Pindyck, "The Economics of the Natural Gas Shortage (1960–1980)," North-Holland, Amsterdam (1975).
25. D. Ricardo, "The Principles of Political Economy and Taxation," G. Bell & Sons, London (1817).
26. R. Rorty, "Philosophy and the Mirror of Nature," Princeton Univ. Press, Princeton, NJ (1979).
27. J. L. Simon and H. Kahn (Eds.), "The Resourceful Earth: A Response to Global 2000," Blackwell, New York (1984).
28. M. E. Slade, Trends in natural resource commodity prices: An analysis of the time domain, *J. Environ. Econom. Management* **9**, 122–137 (1982).
29. V. K. Smith (Ed.), "Scarcity and Growth Reconsidered," Johns Hopkins Press, Baltimore (1979).
30. R. M. Solow, The economics of resources or the resources of economics, *Amer. Econom. Rev.* **64**, 1–14 (1974).
31. J. Swierzbinski and R. Mendelsohn, Information and exhaustible resources: A Bayesian analysis, *J. Environ. Econom. Management* **16**, 193–208 (1989).