Energy and Depletable Resources:

Economics and Policy, 1973-98

by

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Abstract

This paper reviews the impact of the literature in depletable resources and energy economics over the period 1973-98, particularly the period of publication of the *Journal of Environmental Economics and Management*, 1974-98. A discussion of prominent policy issues in this arena is provided, along with an indication of what academic economics papers have contributed to that debate. This is followed by a citation analysis of contributions in the fields of energy and exhaustible resource economics. For each of these two fields, a list of the top papers in each five year period from 1974 to 1998 is presented, along with a list of the top journals in each decade, based on average citations per article. The top ten cited articles in the fields in the *Journal of Environmental Economics and Management* is also presented.

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I INTRODUCTION

In the area of depletable resources, much has happened in the quarter century since the *Journal of Environmental Economics and Management* (JEEM) began publication. Though the first issue of the Journal was May 1974, the idea of the Journal and the typescript for most of those first papers undoubtedly date from the period when energy was cheap[2] and OPEC had yet to flex its muscle. The Fall of 1973 brought the OPEC oil embargo, the resulting energy price shock, and the rest is history. For much of the following decade, energy dominated the research agenda in the area of depletable resources. With the collapse in the oil price in 1986, energy issues faded from the agenda for a few years, only to re-emerge in the guise of climate policy in the late 1980's and 1990's.

Non-energy issues in depletable resources were also prominent in the early days of JEEM. In the 1960's Barnett and Morse (1963) published their classic analysis of the extent to which resources were becoming more scarce. The 1970's saw renewed interest in these scarcity issues, prompted by oil price rises as well as price increases for many other exhaustible resources. In the late 1970's, Kerry Smith (1979) assembled a group of scholars to reexamine the results of Barnett and Morse.

[2] Although the oil price rise did not occur until the Fall of 1973, energy was beginning to be a serious policy concern before that date. In December 1971, the Ford Foundation commissioned a very substantial study of US energy policy, the *Energy Policy Project* (Ford Foundation, 1974). (This was followed up by another study in the late 1970's, Landsberg et al, 1979.) In late 1972, potential shortages in natural gas supply (due to gas price controls) were expected by some industrial users of gas in the US, particularly electricity generators in Texas and Oklahoma. In 1972 and 1973, Western

At approximately the same time, Margaret Slade (1979) published her classic articles on the effect on price of the interplay between depletion and innovation in the technology of extraction.

The charge in producing this contribution for this special issue of JEEM was to determine the extent to which the economics literature, particularly JEEM, has contributed to and supported the development of policy in the area of exhaustible resources. This is not an easy task. In particular, what objective evidence is there of what academic research has contributed to making policy?

The approach taken here, albeit imperfect, is to first provide a very subjective review of what major policy issues faced the world over the last quarter century in the area of exhaustible resources (a modest task!)[3]. For the most part, this review of policy issues will focus on energy. This is for two reasons. Energy has certainly dominated the resources agenda over the last quarter century. But further, the author is more familiar with the policy issues in the energy arena. This later justification explains the focus on US energy problems.

Taking off from this beginning, the remainder of the paper will rely on the published literature to both frame what was of interest (i.e., interest will be defined by articles published) and what sources were used in that policy research (i.e., citations to published articles).

US coal production was beginning to gear up to serve as an alternative fuel for electricity generation, in part due to stricter emission regulations brought about by the 1970 Clean Air Act Amendments.

[3] There are other reviews of this literature. For instance, see Peterson and Fisher (1977) and Fisher and Peterson (1976).

II. THE POLICY ISSUES, 1973-1998

Looking back over the last quarter of a century, there appear to be four basic issues that have dominated the energy debate, broadly defined, at least in the US: what will happen to prices?; to what extent is intervention in the market desirable?; what are the consequences of price changes in the market?; and what should be the nature of government intervention when it is necessary? Each of these is a fairly broad subject with a variety of subissues which we can individually examine.

A. Whither Energy Prices?

The 1973 oil price rise[4] certainly caught the attention of consumers around the world, although in many ways it was the physical shortages brought on by the Arab oil embargo (associated with the Yom Kippur war in Israel) and price controls in the US that most concerned the general public.[5] For the remainder of the decade of the 1970's the price of oil and other forms of energy was one of the primary energy policy concerns. Will the Organization of Petroleum Exporting Countries (OPEC) be able to keep prices high? How high can OPEC push prices? How does OPEC work? Will they fall apart? What effect will depletion of energy supplies have on price? More specifically, how will continuing depletion of fossil fuels affect the profile of prices over time? Can we rely on the Hotelling model? To what extent will elevated energy prices induce increased supply of energy and how quickly can this be expected to

[4] In October 1973 the price of crude oil went from under $2/barrel to over $10/barrel. [source?]
[5] The Ford Foundation (1974) report on energy policy published in 1974: "The energy crisis seems to have vanished as suddenly as it appeared. The gasoline lines are have gone and auto companies are again advertising big luxurious cars."

happen? And what effect will the increased supply have on price? To what extent will elevated prices reduce energy consumption and what effect will this have on price?

These questions are at the same time policy questions and fundamental questions about how markets work. Understanding the behavior of cartels, particularly OPEC, was a major research area in the 1970's and 1980's.[6] This involved studying both the operation of cartels as well as the operation of the specific cartel called OPEC. Pindyck (1978) actually computed the profit maximizing cartel prices for several cartels. Much was made of Hotelling's rule for the pricing of an exhaustible resource, both in a competitive environment as well as a monopolistic environment. Sweeney (1976) and Stiglitz (1976) both clarified the Hotelling rule in the presence of monopoly and Gilbert (1978) and Salant (1980) extending this to the case of a dominant producer with a competitive fringe and several dominant producers. Pindyck (1982) and Kolstad (1994) extended the model to several imperfectly substitutable exhaustible resources. A number of papers attempted to empirically validate Hotelling's model, without a great deal of success, one way or the other. The most well known of these efforts is Miller and Upton (1986).

The issue of the extent to which elevated prices will bring forth new supply and restrict demand was addressed primarily on the demand side. A great number of empirical analyses concerned the econometric estimation of energy demand. These

[6] The literature on cartel and OPEC behavior is voluminous. See Griffin and Teece (1982) for a review. A number of theoretical models, models that have since been influential, were published in the European Economic Review in 1976; see Cremer and Weitzman (1976) and Hnyilicza and Pindyck (1976). Griffin (1985) provides an innovative empirical test of different models of OPEC behavior.

are too numerous to mention but the papers of Griffin and Gregory (1976) and Berndt and Wood (1975, 1979) were some of the more influential contributions to this literature.[7] A related issue concerns the extent to which elevated energy prices will induce research and development to increase the fuel efficiency of energy-using capital. The mechanism of price-induced technological change is poorly understood today, despite progress over the decades.[8]

B. The Consequences of Energy Price Increases

Of course, when the price of any major commodity rises by a factor of five, as oil did in late 1973, the immediate reaction in policy/government circles is that the price rise is harmful. While that is probably the case, the question remains as to how harmful? With inflation accelerating at approximately the same time as the oil price rises in the 1970's, to what extent should oil price rises be considered to spur inflation? If there is a causal connection, then inflation may subside when oil prices stabilize. Other than inflation, are there other macroeconomic impacts of oil price increases?

Similarly coincident with the oil price rise was the productivity slowdown of the 1970's. Productivity growth had been at high levels in many countries in the post-World War II era. For many industrialized countries, productivity growth ground to a halt (or significantly slowed) in the 1970's and 1980's. To what extent

[7] Slade et al (1993) provides a relatively recent review of some of this literature. Berndt and Field (1981) includes a number of papers covering the breadth of approaches to measuring the demand for energy.

[8] Kamian and Swartz (1969) presented one of the earlier models of price induced technical change. More recently, Jaffe and Stavins (1994) empirically examined the evolution of efficiency in window air conditioners in response to the price of electricity.

should the price of energy be held responsible for this?[9] Once again, if energy price rises are a culprit, then stabilizing prices should help.

Another totally separate issue, is the effect of energy price increases (and decreases) on countries that are significant energy exporters. The so-called "Dutch Disease" was identified as a problem with countries which had significant resource exports (Corden, 1982). The idea is that heavy resource exports cause the domestic currency to appreciate; this tends to cause domestic capital to move to the resource sector, causing the industrial sector to wither. This seems to have operated in reverse in the recent collapse of the Russian ruble. Russia was heavily reliant on oil and gas exports; when oil prices plummeted in 1998, the ruble collapsed as well. There are of course many other problems in the Russia of 1998, in addition to declining oil prices.

C. Where Should the Government Intervene?

In the years following the 1973 oil price rise, energy policy in the US could be characterized as generally suspicious of the market.[10] The price of oil products was controlled from the beginning of the oil price rise. Natural gas prices had been controlled for years. Electricity prices were also controlled, though for different and more justified reasons (electric utilities were regulated monopolies). Despite these price controls, energy prices did rise, though somewhat more slowly than would have been the case without the controls. A major issue was the extent to which the

[9] The consensus now is reflected in Jorgenson and Wilcoxin (1990), who estimate that the effect of environmental regulations on productivity was quite modest.

market could be relied upon to solve the "energy crisis." Would elevated energy prices induce sufficient conservation? Would elevated energy prices induce expanded energy supply? Would elevated energy prices induce sufficient innovation to reduce the energy intensity of production and consumption? The general consensus in early years was that it was not enough to rely on the market, in part (but certainly not entirely) for the very real reason that price controls were preventing proper signals from reaching the marketplace.

Soon after the 1973 price action, the US government embarked on a very large effort to analyze the operation of the energy market, predict how the market might evolve, and determine appropriate interventions that might reduce the negative impacts of the market on the US economy. This was "Project Independence" (Hausman, 1975). Supply augmentation was a major strategy pursued by the US government in addressing the "energy crisis." This involved programs to expand the use of energy resources on Federal lands, to increase R&D into supply technologies, and probably most visible (and expensive) of all, to promote the development of a synthetic fuels industry by funding demonstration synfuels facilities.[11] This strategy was strongly criticized by Amory Lovins (1976) who argued that the energy market would respond to increased prices, greatly decreasing the quantity of energy demanded.

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[10] In the Ford Foundation (1974) report on energy policy, it is striking that several members of the advisory board for that study criticized the study's reliance on federal planning as opposed to the market mechanism in implementing energy goals.

[11] See Weitzman et al (1981) for a discussion of synfuels programs. Schmalensee (1980) addresses the general issues of government subsidies to new energy supply technologies.

There was also distrust of the market on the demand side of the equation, although in some cases with good reason. Would consumers demand fuel efficient cars and would automakers provide them? Would consumers demand fuel efficient houses and would building contractors supply them? For an answer, the general consensus was "No."[12] A major tool used to "correct" the market's imperfections was the fuel efficiency standard, applied to buildings, appliances, and automobiles.

With hindsight, it is still an unresolved question of how much of the reduction in the quantity of energy consumed was due to price induced conservation as opposed to fuel efficiency standards. Today, in the context of the climate change debate, the question remains of how easily/cheaply energy consumption can be reduced in order to reduce emissions of greenhouse gases. There are two major camps on this issue. One school of thought is that there are numerous opportunities to reduce consumption; it is just that these opportunities have not yet been adopted. The other view is that price is the signal to which consumers respond and if existing technologies have not been adopted it is because consumers have concluded that these technologies are not useful, given relative prices.[13]

The security dimensions of energy supply have always been viewed as appropriate concerns of the government: most analysts do not view the market as

[12] Why the answer should be "No" has been the subject of a fair amount of research. Ohta and Griliches (1986) investigated consumer preferences regarding automobiles. Atkinson and Halvorsen (1984) examined how consumers make choices regarding fuel efficiency and other automotive characteristics. Some of this automobile-related literature is summarized in NRC (1995). In the area of appliance choice, Hausman (1979) examined consumer time preferences in trading off up-front costs for fuel efficiency with delayed expenditures for fuel. Dubin and McFadden (1984) constructed new econometric techniques to quantify consumer choices regarding appliances.

[13] This is a very long-standing debate, most recently referred to as the "top-down" vs. "bottom-up" approach to analyzing energy consumption (see Hourcade et al, 1996 and Weyant, 1998).

providing sufficient signals to address the problems of the disruption of energy supply due to crises overseas. One could argue that the Gulf War in the early 1990's was simply a form of energy policy, protecting western oil supplies originating in the Middle East.[14] Certainly the dependence of the US on foreign sources of oil in the 1970's was a major concern, implicit in the name "Project Independence," the massive U.S. Government analysis effort to "solve" the energy crisis of the early 1970's. Security was also viewed as threatened by sudden fluctuations in the price of oil: thus the establishment of the Strategic Petroleum Reserve (SPR). The SPR is a large store of oil in abandoned salt domes. The idea is that if the price of oil were to rise rapidly due to a disruption in supply, then the SPR could be called upon to provide supplies, thus reducing the price shock. Ever since the SPR was established, there has been controversy over exactly how or when the reserve would be used.[15] The logic was that if a crisis occurred, and prices were driven up, the natural reaction would be to save the stored oil in case things became worse. Only when the crisis began to ease would managers feel comfortable in releasing stored oil; but then the need would have largely passed. So the reserve would remain unused. A more fundamental question regards the necessity and desirability of providing a price buffer; other commodity prices fluctuate without leading to catastrophe.

[14]Another security issue, of a somewhat different nature, pertained to Western European reliance on natural gas provided by the then Soviet Union. This was an issue in the early 1980's and the question was whether it was in the best interest of the US and/or Europe to heavily rely on natural gas from Soviet sources.

[15] Teisberg (1981) provided one of the earliest analyses of how to use the SPR. For a recent discussion of the SPR, see Blumstein and Komor (1996).

It is a well-known fact in economics that research and development (R&D) will not be provided at efficient levels by the private market, at least if there are any knowledge spillovers that cannot be appropriated by the innovator, which is usually the case for basic research. Thus an appropriate role for the government is in financing R&D. The conclusion of this debate during the 1970's was that energy research that is risky with a payoff far in the future (more basic than applied research) is appropriate for the government to fund while research with near-term payoff, particularly in terms of commercial payoff, is appropriate for the private sector. But this doesn't mean that all long-shots should be financed by the government. How to decide where to put public R&D monies?[16] And after the fact, how efficient is government R&D, absent the profit motive found in industry? Related to this, if commercialization of a technology (for example, photovoltaics) is a goal, is there any action the government can take to promote this commercialization? Although many felt that an assured governmental market would be all that is necessary to spur private development, the question remains largely unanswered.

D. The Nature of Government Intervention

It some arenas, it is clear that the government has a role to play in energy markets. At the simplest level, many governments, including the US government, own significant energy resources. How should these resources be developed? What institutions should be used to move them into the private sector?

[16] This issue of public R&D funding of energy was addressed by Roberts and Weitzman (1981). It has resurfaced in the current greenhouse debate in the context of the value of information about climate

Electric utilities have traditionally been viewed as natural monopolies and as such have been regulated. With the price rises of the 1970's, the question naturally arose as to whether there were distortions introduced by the way in which utilities were regulated which might exacerbate the introduction of new technologies or the pursuit of energy conservation. One view was that utilities were somewhat insulated from risk and market pressures and thus were excessively pursuing costly technologies such as nuclear power, at the expense of cleaner but less exotic forms of energy supply or energy conservation. One institutional change which had profound effects on the industry was the Public Utilities Regulatory Policies Act of 1978, which among other things required utilities to purchase power from third parties at the "avoided cost" associated with buying that power – i.e., the savings from not having to generate power from a conventional source.

This was the beginning of a fundamental examination of just what components of the electric utility business needed to be regulated. In the early 1980's, Paul Joskow and Richard Schmalensee (1983) published an influential book on using markets to govern the operation of the electricity sector in the U.S. The deregulation of the electric power industry caught on overseas quite quickly. The UK was the first country to deregulate all but the transmission grid. Many other countries or regions have since followed suit. Only this year (1998) has a major US state taken this step – California, though many are in the process of doing so.

Environmental protection is another obvious arena for government involvement. Clearly the market does not supply an efficient amount of

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uncertainties (see Manne and Richels, 1992, Peck and Teisberg, 1993 and Kolstad, 1996).

environmental protection. The environment has been a constant companion to energy policy deliberations over this entire quarter-century. In the late 1960's the question of black lung disease affecting underground coal miners was the subject of legislative attention. In the 1970's, the damage brought on by unregulated strip mining of coal was addressed with legislation. Also in the coal vein, much of the coal in the Western U.S. is owned by or controlled by the federal government. In the mid-1970's, leasing of that coal became bogged down with concerns over the environmental effects of leasing and mining. Air pollution consequences of significant energy development in the pristine and fragile intermountain west was a significant issue. All of the nation's rich oil shale reserves were in western Colorado, not far from many national parks and other pristine areas.

In the late 1980's the issue of climate change resurfaced (it was also an issue in the 1970's). Here the issue is the extent to which the government should intervene to reduce the emissions of greenhouse gases, largely carbon dioxide from fossil fuel combustion. Many of the same issues that have dominated the last twenty five years of energy policy have resurfaced in the climate change debate. For instance, the question of how consumers of energy respond to price signals is just as important now as it was in the 1970's. In the 1970's a central question was how fast new technologies would emerge to reduce energy use. The variant for the 1990's is how fast carbon-saving technologies will emerge in response to a regulation such as a carbon tax.

III. THE ECONOMICS LITERATURE, 1974-1998[17]

It is one thing to identify the energy and resource policy issues of the last quarter century. It is quite another thing to quantify the importance of the academic economics literature in solving these policy questions. In the above policy discussion, an attempt was made to identify important economics papers that had addressed the policy issues enumerated. Beyond this, it is quite clear that economics research generally was instrumental in the formulation of overall energy policy and the resolution of energy-related problems. The abandonment of heavy price regulation of oil and gas in the 1970's was undoubtedly the result of the accumulation of literature on the problems wrought by regulating various sectors of the economy. Coincident with deregulation of oil and gas was deregulation of trucking, airlines and railroads, among other industries. It is difficult to attribute this policy shift to any one paper or group of papers.

Instead of attempting to answer the question of which journal articles influenced the policy process the most, we will answer the much easier question of which journal articles in certain topical areas were the most influential in academic research. This is a question which can be addressed with citations (see Laband and Piette, 1994). A paper that is used in many other papers (ie, is referenced) is considered to be more valuable than a paper that has been referenced in fewer

[17] The period 1974-98 is chosen for an examination of the literature (rather than 1973-98) because JEEM did not start publication until 1974.

papers. This is of course an imperfect measure, suffering from problems such as self-cites by the author (which are not excluded in our analysis).[18]

The two areas of scholarship we will examine are exhaustible resources[19] and energy[20]. We are interested in what papers have been the most "useful" (ie, cited) over the past quarter century and we are also interested in which journals have been most influential in these topic areas.[21] It turns out to be important to ask these questions at different points in time because journals definitely rise and fall within specific areas of research in economics. In the 1970's, the *Review of Economic*

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[18] There are many other problems with using citations as a measure of value. If two papers were published in different years, then they have been available for citation over different periods. A citation is not necessarily a measure of value. Papers that others find fault with are often cited negatively. Survey papers attract many cites but are not necessarily contributions to economics. The quality of the citing paper is often ignored in tallying up cites. The problems with using citations as a measure of value are well documented elsewhere.

[19] From the point of view of the computer search of papers on exhaustible resources, we have defined the appropriate set of papers as ones containing any of the words "exhaustible," "depletable," "nonrenewable," "mineral," "minerals," "natural resources, not valuation" or "natural resource, not valuation." The reason for excluding valuation is that natural resource damage assessment has come to be the moniker for valuing environmental resources, without concern for whether they are renewable or nonrenewable resources. These identifying words would appear in the title, abstract or list of key words. Prior to 1990, papers with the word "resource" or "resources" were also included; this is a broad category from which inappropriate papers were manually culled, as they were in all other automated searches.

[20] From the point of view of the computer search of papers on energy, we have defined the appropriate set of papers as ones containing the words "energy," "oil," "petroleum," "coal," "gas," "electricity," "greenhouse," "global warming" or "climate change." These identifying words would appear in the title, abstract or list of key words.

[21] Citations were generated by searching the Social Science Citation Index, using the Web of Science, an internet resource for searching the Citation Index. Citation data is as of October 20, 1998. Because the word energy is so ubiquitous, we limited the search to the following economics journals: *American Economic Review, Canadian Journal of Economics, Economic Journal, Environmental and Resource Economics, Journal of Environmental Economics and Management, Journal of Economic Theory, Journal of Law and Economics, Journal of Political Economy, Journal of Public Economics, Journal of Urban Economics, Land Economics, Natural Resources Journal, Quarterly Journal of Economics, Review of Economics and Statistics, Review of Economic Studies, Bell/Rand Journal of Economics, Southern Economic Journal, Scandinavian Journal of Economics, Resource and Energy Economics, Swedish Journal of Economics, Econometrica, Economic Journal, Energy Journal, American Journal of Agricultural Economics,* and the *Journal of Development Economics.* Not all of these journals were indexed during the 1974-98 period. For instance, the Energy Journal began being indexed in 1994. Furthermore, there are other journals that publish economics articles that are not included. It is hoped the main outlets are included, however.

Studies was the most important journal in terms of energy economics; it had virtually disappeared from the radar screen in this area by the 1990's.

A. The Most Cited Papers

Table I shows the top three cited papers on energy in each of the five year periods 1974-8, 1979-83, 1984-8, 1989-93, 1994-8, spanning JEEM's history.[22] Note that it the first decade, the most cited energy papers were dominated by two papers by Ernst Berndt and David Wood. Both papers were concerned with the relationship between energy and capital in an aggregate production function of the manufacturing sector. The issue was whether energy and capital were substitutes or complements. If substitutes, then capital could take the place of energy over time; if complements, then growth in the capital stock would involve more energy consumption. It wasn't at all clear *ex ante* which should be the case. It seemed plausible that more efficient capital could replace energy. It also seemed plausible that energy use accompanies capital – more capital, more energy. Thus it was an empirical question that Berndt and Wood not only introduced to the profession but were used to clarify the nature of energy demand. In the 1980's, attention shifted to industrial organization issues associated with coal contracts and property rights problems associated with oil production. These were important issues as the US moved towards a reliance on markets for the management of energy resources. Then as we turn to the 1990's, we find that the agenda is dominated by concern for climate change. In fact, of the top six papers in the 1989-98 period, four of the six concern the greenhouse effect (and

half of them are authored or co-authored by William Nordhaus, a leader in this arena).

Table II presents a similar set of figures for the exhaustible resource area. The 1970's were a time of profound growth in the exhaustible resource literature. A number of very influential articles emerged in that time period, particularly regarding optimal depletion. In the 1980's the profession turns to the question of scarcity, starting with Margaret Slade's important paper on the interaction between depletion and technological change in determining resource prices. A long-standing debate concerned the extent to which resources were becoming more scarce. Obviously, mining of resources leaves less physical quantity in the ground. However, most measures of scarcity had shown that resources were becoming more plentiful. Slade (1982) attempted to measure the dual changes in scarcity and technical progress in extraction, pointing out that eventually scarcity should overtake technical progress. Several other papers in the 1980's pick up on the theme of measuring resource scarcity. In the 1990's the dominant theme becomes sustainability and the question of how to modify national accounts to reflect natural resources and the environment.

If one compares Table I and Table II, it is striking that energy has received much more attention in the literature than non-energy exhaustible resource issues. This may be because energy is considered to be more closely tied to policy issues.

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[22] We should note that the search on the energy topic was imperfect. We know, for instance, that we failed to pick up the important paper by Miller and Upton (1985), testing the Hotelling principle on the oil market.

Nearly all papers in Table I are empirical whereas a significant number of papers in Table II are theoretical.

B. The Most Cited Journals

We have seen the papers that had the most impact on energy and exhaustible resources. Which journals tended to have the most impact? An examination of citation rates indicates that there are clear leaders among the journals. The citation rate is the average citations per article in a subject area over a specific period of time.[23] Using citation rates to rank journals, Table III lists the top five journals in exhaustible resources (excluding energy) during each of the three decades of interest to us here. The first thing to notice is that there were more seminal articles in the 1970's. The top four journals have citation rates exceeding 30 cites per article, a rate that has not been achieved since. In fact, with the exception of the JPE, no journal has topped a rate of 10 since 1980. There is of course some bias built into this measure in that earlier papers have longer to accumulate citations. Nevertheless, a glance at Table II will support the contention that the 1970's were a time of high impact papers. The *Journal of Political Economy* dominated the first two decadal periods, not with the number of papers (only a paper every other year) but with the impact of these papers. The *Review of Economic Studies* was very prominent in the 1970's but become totally uninfluential by the 1980's. The same can be said of the *Bell* (now *Rand*) *Journal of Economics*. It was a big player in the 1970's but has been absent since then. JEEM has been very prominent in this field, finding itself in the

[23] If there are n papers during a specified period of time in a topic area in a journal and there are m cites to those n papers, occurring anywhere at any time, then the citation rate is m/n.

top five list during the 1980's and 1990's. In the 1990's the *Natural Resources Journal*, a combination law, policy and economics journal, long respected in the natural resource area, receives deserved recognition by being in the top five.

Table IV presents similar data for the field of energy economics. Certainly the 1970's were a time of highly productive journals but the field has not dropped in activity as much as non-energy exhaustible resources. The citation rate continued at a brisk pace in the 1980's and into the 1990's. Furthermore, the "general interest" journals such as the *JPE* and the *AER* have continued to be prominent in the field up to the present. In fact the only "field" journals to make the list are the *Bell/Rand Journal of Economics* (an IO oriented journal) and the relatively new journal, *Resource and Energy Economics*.

The results in Tables I-IV suggest that the life-cycle of a field of study begins with several very influential papers, followed by a much larger quantity of papers, on average less influential. Though there may still be influential papers after the beginning of research in an area, the sheer numbers of papers tend to dilute the measures of journal impact. Furthermore, field journals, by their very nature, are an outlet for a much larger quantity of papers, many of which are important but not necessarily ground breaking. This is not a criticism but a reality. Thus one would expect citation rates to be lower for field journals.

C. The Impact of JEEM

One question that is of importance in this special issue of JEEM is how well JEEM has done in the energy and exhaustible resources field. The citation impacts tell one story and that is that JEEM has been visible and prominent in the exhaustible resources field but somewhat less visible in energy.[24] Table V lists the articles in the combined fields of exhaustible resources and energy that appeared in JEEM and have had the most citations over the past quarter century. Note that every one of these papers is in exhaustible resources rather than energy. JEEM has had important energy-related papers; the top cited paper (Cassler and Hannon, 1989) received eleven citations. But because of the significance of the non-energy exhaustible resource papers, this was not enough to make the top ten list.

Historically, the environment has not been central to the energy economics literature, a traditional focus of JEEM. Of the next five top cited energy papers in JEEM, all of them concern pollution – oil spills, the sulfur allowance system in the US or global warming. As has been pointed out in the context of Table I, in the 1990's the energy literature is dominated by the question of global warming. It would thus be very plausible that a 2009 (a decade from now) retrospective of JEEM's presence in the energy area, would find very significant impact during the 1990s'.

IV CONCLUSION

[24] JEEM's average citations per article in the energy area during the 1990's is 1.9, a rate that makes it a close contender for the "top five" list of journals in energy during the 1990's.

This paper has examined the contribution of the economics literature to the policy and academic debate over exhaustible resources and energy over the last quarter century. This has been an exciting and productive period for economics. Each decade from the 1970's to the 1990's has involved different policy and economics issues. In the 1970s', energy demand and OPEC behavior were of foremost interest. In the non-energy exhaustible resource arena, the question of optimal depletion dominated the agenda. In the 1990's sustainability is dominant in the resources arena whereas global warming dominates the energy field. In some sense, environmental concerns are now the dominant force in shaping both exhaustible resource and energy economics.

The *Journal of Environmental Economics and Management* has been a visible and influential journal over this entire period. Several of the classic, top-cited papers to appear anywhere over the last quarter century appeared in JEEM. This trend shows no sign of changing; if anything, JEEM will become more prominent in the next millenium.

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Table I: Top three most cited energy papers in each five year period, 1974-98.

NB: Excludes survey papers; the energy field is defined in a footnote to the text as is the set c using the Social Science Citation Index.

1974-8
Berndt and Wood (1975), "Technology, Prices and the Derived Demand For Energy"
Hudson and Jorgenson (1974), "US Energy Policy and Economic Growth, 1975-2000"
Griffin and Gregory (1976), "Intercountry Translog Model of Energy Substitution Responses"

1979-83
Berndt and Wood (1979), "Engineering and Econometric Interpretation of Energy-Capital Com
Hausman (1979), "Individual Discount Rates and the Purchase and Utilization of Energy-Using
Hamilton, J.D., "Oil and the Macroeconomy Since World War II"

1984-88
Joskow (1987), "Contract Duration and Relationship-Specific Investments – Empirical Evidence from Coal Markets"
Balassa (1985), "Exports, Policy Choices, and Economic Growth in Developing Countries after the 1973 Oil Shock"
Libecap and Wiggins (1984), "Contractual Responses to the Common Pool – Prorationing of Crude Oil Production"

1989-93
Perron (1989), "The Great Crash, the Oil Price Shock, and The Unit-Root Hypothesis,"
Nordhaus (1991), "To Slow or Not to Slow – The Economics Of the Greenhouse Effect"
Schelling (1992), "Some Economics of Global Warming"

1994-98
Mendelsohn et al (1994), "The Impact of Global Warming on Agriculture – A Ricardian Analysi
Fankhauser (1994), "The Social Costs of Greenhouse-Gas Emissions – An Expected Value Appr
Newberry (1995), "Power Markets and Market Power"

Table II: Top three most cited nonrenewable resource papers in each five year period, 1974
NB: Excludes survey papers; the nonrenewable resource field is defined in the text as is the
covered.

1974-8
Solow (1974), "Economics of Resources or Resources of Economics"
Ciriacy-Wantrup and Bishop (1975), "Common Property as A Concept in Natural Resources Po
Solow (1974), "Intergenerational Equity and Exhaustible Resources"

1979-83
Slade (1982), "Trends in Natural Resource Commodity Prices – An Analysis of the Time Doma
Stollery (1983), "Mineral Depletion with Cost as the Extraction Limit – A Model Applied to the
Behavior of Prices in the Nickel Industry"
Arrow and Chang (1982), "Optimal Pricing, Use and Exploration of Uncertain Natural Resourc

1984-88
Solow (1986), "On the Intergenerational Allocation of Natural Resources"
Hall and Hall (1984), "Concepts and Measures of Natural Resource Scarcity with a Summary o
Halvorsen and Smith (1984), "On Measuring Natural Resource Scarcity"

1989-93
Hartwick (1990), "National Accounting and Economic Depreciation"
Schlager and Ostrom (1992), "Property Rights Regimes And Natural Resources – A Conceptual
Howarth (1991), "Intergenerational Competitive Equilibria Under Technological Uncertainty a
an Exhaustible Resource Constraint"
1994-98
Asheim (1994), "Net National Product as an Indicator of Sustainability"
Toman (1994), "Economics and Sustainability – Balancing Trade-offs and Imperatives"
Lopez (1994), "The Environment as a Factor of Production – The Effects of Economic Growth a
Trade Liberalization"

Table III: Five Highest Impact Economics Journals in Exhaustible Resources

NB: Average citations per article is used to rank journals. Excludes journals with only one p
decade.

Journal	# Cites	# Articles	Avg Cites per Article
1974-79			
Journal of Political Economy	156	3	52
Review of Economic Studies	463	12	39
Bell Journal of Economics	114	3	38
American Economic Review	157	5	31
Quarterly Journal of Economics	88	4	22
1980-89			
Journal of Political Economy	85	4	21
Scandinavian Journal of Economics	87	5	17
Journal of Env. Econ. and Mgmt.	227	30	7.6
Econometrica	23	5	4.6
Quarterly Journal of Economics	18	4	4.5
1990-98			
Journal of Public Economics	57	8	7.1
Scandinavian Journal of Economics	35	5	7.0
Land Economics	52	17	3.1
Journal of Env. Econ. and Mgmt.	59	32	1.8
Natural Resources Journal	33	22	1.5

Table IV: Five Highest Impact Economics Journals in Energy

NB: Average citations per article is used to rank journals. Excludes journals with only one p
decade.

Journal	# Cites	# Articles	Avg Cites per Article
1974-79			
Review of Economics and Statistics	523	9	58
Bell Journal of Economics	898	18	50
Journal of Political Economy	59	2	30
American Economic Review	386	16	24
Quarterly Journal of Economics	26	2	13
1980-89			
Journal of Political Economy	208	6	34
American Economic Review	293	12	24
Bell/Rand Journal of Economics	280	25	11
Review of Economic Studies	29	3	10
Quarterly Journal of Economics	66	7	9.4
1990-98			
Journal of Political Economy	41	3	14
American Economic Review	220	17	13
Rand Journal of Economics	52	9	5.8
Review of Economics and Statistics	51	20	2.6
Resource and Energy Economics	150	64	2.3

Table V: JEEM's Greatest Hits in Depletable Resources and Energy

NB: Citations are from the Web of Science version of the Social Science Citation Index, as of
Definitions of fields may be found in the footnotes in the text.

RANK	AUTHOR	TITLE	YE
1	Slade	"Trends in Natural-Resource Commodity Prices – An Analysis of the Time Domain"	198
2	Smith	"Control Theory Applied to Natural and Environmental Resources – Exposition"	197
3	Schulze	"Optimal Use of Non-Renewable Resources – Theory of Extraction"	
4	Hall & Hall	"Concepts and Measures of Natural Resource Scarcity with a Summary of Recent Trends"	198
5	Burness	"Taxation of Non-Replenishable Natural Resources"	197
6	Arrow & Chang	"Optimal Pricing, Use and Exploration of Uncertain Natural Resource Stocks"	198
7	Smith	"Measuring Natural Resource Scarcity – Theory and Practice"	197
8	Johnson et al	"Natural Resource Scarcity – Empirical Evidence and Public Policy"	198
9	Peterson	"Model of Mining and Exploring for Exhaustible Resources"	197
10	Heaps	"The Taxation of Nonreplenishable Natu ral Resources Revisited"	19