2 A short history of environmental and resource economics

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1 Introduction
As late as 300 years ago, nearly everyone was fatalistic about nature. Whatever transactions people undertook left all but their immediate environment and the social order in which they nested pretty much undisturbed (Chayanov, 1966; Sahlin, 1974). People lived in self-contained groups which left them few options but to adapt to the idiosyncrasies of their natural surroundings. Many were unlucky and suffered famine, flood and pestilence. The intellectual ferment of the eighteenth-century Enlightenment changed this. Over about two centuries the idea that the social order may influence nature - for good - spread over the world. A broad consensus that this same order may also influence nature for ill was reached only in the last half of the twentieth century. Though economists have studied the original endowment of the earth since the beginnings of their discipline, it took an awakening realization in 1950s North America that all was not well with the management of the region's natural resource asset base to make environmental and resource economics (resource economics, for brevity) a distinct field.

As in general economics the history of resource economics can be viewed as a sequence of thought experiments or models and organized empirical observations directed at a common set of questions about economic scarcity and thus choice. For resource economics the models and the findings are meant to explain roles that the natural environment plays in decisions under the curse of Adam and Eve, decisions that are a universal problem of the human condition and which therefore should be of keen interest to all, economists and non-economists alike. This brief essay traces the contributions of economics to the evolution of approaches to this problem and the forms these approaches currently take in the specialized field of resource economics.

2 Predecessors
In order to hear their modern echoes, this section portrays the thinking of the pre-World War II predecessors to the modern field of resource economics. According to Smith (1776), Ricardo (1817) and Marx (1865), natural resources are worthy of distinctive analytical treatment because the services they offer are gratis. Payments to the owners of the resources are therefore rents or unearned increments. Marshall (1920) concluded that such payments combine rents and royalties because extraction of the potential services that nature freely provides requires effort. Exhaustibility was not an issue, but, because resources differ in their service potentials, depletion may be realized by different declines in the quality of supply sources. Such declines were shown to be the source of dissimilar land rents across space.

Exceptions to this early, rather sterile debate about labels were few and melancholy. Malthus (1798) told a grim tale of immiseration caused by limited agricultural land and exponential population growth. Darwin (1876, p. 388) granted that this tale inspired his theory of evolution. The rising land rents induced by diminishing returns were the ultimate check upon growth in population and in wealth (Ricardo, 1817). George (1879) worried about the wealth and power consequences of landowners' unearned rents. Jevons (1865) gloomily spoke of industrial decay due to the depletion of the quantity and quality of coal stocks. Other than Mill's (1865, p. 750) brief remarks, no economist of stature deliberated upon the life support and amenity services that natural environments offer. Except for Faustmann's (1849) prescient treatment of the optimal time to harvest a forest when current harvesting affects the growth and thus the time distribution of future returns, and Pressler's (1860) use of the same problem to anticipate marginal analysis, questions that would later become prominent about optimal rates of resource depletion and levels of environmental quality were simply not asked. Natural resources were regarded as another factor of production similar, aside from their free provision by nature, to heterogeneous capital which never gets out of the market process. In modern terms the economics of the time offered up a simple present-value maximization criterion in an assumed setting of complete markets. The criterion was thereby blind to the life support and amenity services of the environment and presumed that present consumption of resource stocks did not impact on future consumption and production opportunities.

Not until the early twentieth century did economists begin to explore systematically the tension between present-value maximization as if the entire economy were a single, fully informed, incentive-compatible firm indifferent to the foreclosure of its future options and to the depletion and non-market features which pervade natural resource issues. Gray (1914) initiated this thrust by showing that in a world of complete markets and rational expectations a firm employing the present-value maximization criterion would distribute its depletable resource extraction activities over time such that its rents would increase at the market rate of interest. A heretofore unrecognized cost over and above the costs of extraction and processing,
the opportunity cost of depletion, or 'user cost', drove this result. Ise (1925) showed how the rent path of the resource was sensitive to the prices of substitutes and other exogenous economic factors. For regenerative biological resources, an opportunity cost of not harvesting, the foregone growth of the stock remaining after the harvest, must also be taken into account. Hotelling (1931) extended Gray (1914) to the entire economy by demonstrating, again in a world of complete markets and rational expectations, that the price for a depletable resource would increase at the rate of interest. Private and socially optimal price paths would coincide. However, Gray (1913) has earlier set aside the complete markets condition to express concern that user costs accruing to future generations would then be inadequately reflected in current extraction decisions. Ely (1918), expressing the same concern about the erosion of society's resource base, proposed to reduce the biases that incomplete markets have for the present by joining economic analysis with the understanding that natural scientists and the like have about the future productive powers of natural resources. Pigou (1920) took the incomplete markets theme further to demonstrate how the price system is likely to understate the collective scarcity value of the life support and amenity services of the natural environment.

During the 1930s, economists' interest in resource questions languished except for the institutionalist school associated with the work of Commons (1934). This enclave, which was virtually a subset of the agricultural economics of the time, insisted that market prices are only a part of the information that economic agents employ to make decisions. The social commitments and norms that property and other collective institutions induce, and the coordination of expectations among agents that they thereby offer, are forms of value expression and social interaction just as valid as those of the market, especially when issues of equity are granted intellectual stature equal to that of allocative efficiency and economic growth. Natural resource institutions were frequently the vehicle employed to carry forward these arguments.

Though natural resources played little if any role in their development, two strands of thought emerged in these interwar years that were to be influential for the evolution of resource economics after World War II. The Austrian school, whose exemplar is Hayek (1937), stressed the subjective nature of human preferences and the dominant roles that information and incentives play in individuals' decisions. Simultaneously, Hicks (1936) and others laid the foundations for inferring individuals' changes in preference satisfaction or welfare from observations of the choices that they make. With these two strands the intellectual tools needed for a resurgence of interest in natural resource economics lay ready at the end of World War II. However, if in the 1930s the United States federal government, drawing upon a tradition in water resources planning going back to Dupuit (1844), had not insisted that proposed federal water developments undergo a rigorous assessment of their benefits and the alternatives that the projects denied, applications of these new tools might well have stalled (Eckstein, 1958). The potential applications of resource economics to water resources planning induced strong demands to advance the state of the art, especially with respect to non-marketed environmental values.

3. Post-World War II
Economic activity consists of two types of transformations: the conversion of resources into goods and services through the creation of form, place, and time utility; and the exchange of the results of these conversions for other goods and money. By the early 1950s, general economics had a set of core behavioural assumptions or working hypotheses in place that allowed it to focus primarily on the second of these transformations. The six conventions are: (1) economic agents exist; (2) these agents have invariant, complete preferences over outcomes; (3) they optimize independently of each other over natural and man-made constraints; (4) their choices are all made in fully integrated markets; (5) they have full, relevant knowledge of their decision problems; and (6) observable outcomes are fully coordinated and must therefore be discussed with respect to equilibrium states (Weintraub, 1985). This core set the stage for tensions which still persist between general economics and resource economics and within resource economics. Because its core conventions did not require recognition that resource conversions were antecedent to the exchange process, general economics has been able to progress by elaborating stylized consistencies between the conventions and equilibrium prices. All economic issues about the environmental and natural resource base are implicitly assumed to have already been solved. Too infrequently, says some observers (McCloskey, 1983), are the consistencies used to design empirical tests of specific hypotheses and to interpret the sources and the consequences of observed events related to exchange. Too frequently are abstraction and mathematical formalism raised above all else and too often is empirical work restricted to a slim set of econometric practices that approved method elevates above systematic observation. In contrast to the well-ordered, narrow path conferred by the universal paradigm of its parent discipline, the frequent demands starting in the 1930s for public policy applications in resource economics have given life to an eclectic interplay between real problems and abstract theory. Though there can be considerable differences among resource economists about the appropriate degree of adherence to the general paradigm (Randall, 1985), there is near-universal agreement that progress in the field demands violations of one or more of the core
conventions, attention to the historical antecedents of problems, and flexibility in empirical method.

Contemporary resource economics departs from the core assumption that all choices are made in fully integrated markets (Kapp, 1950; Coase, 1960). Thinness in markets and in other exchange processes for natural resources, rather than increasing marginal costs caused by diminishing returns in supply, motivate the field to look in depth at the manners in which resource transformations create form, time and place utilities. Questions of internal consistency between the standard behavioural conventions and the formal definition of a general equilibrium set of prices for natural resources as well as for other commodities have, as in Müller (1974) and in Baumol and Oates (1975, attracted occasional interest. Applications of these general equilibrium concepts to the detailed behavioural as opposed to the gross mechanistic properties of economy–ecosystem interactions have only recently appeared (van den Bergh and Nijkamp, 1991; Crocker and Tschirhart, 1993; Swallow, 1996). The field has instead concentrated on the development of auxiliary conditions in partial equilibrium settings which allow at least some features (for example, invariant preferences) of the standard paradigm to fit observed phenomena. Considerable effort has thus been devoted to the task of identifying the exact conditions in a resources context which cause allocation system failures, where 'failure' means that the system fails to exhaust all potential economic surpluses. These sources of failure include rivalrous open access (Gordon, 1954), non-rivalrous indivisibilities in consumption (Samuelson, 1954), informational asymmetries (Weitzman, 1974), non-separabilities (Montgomery, 1976) and non-convexities (Starret, 1972) in production, and transferable externalities (Bird, 1987). The perceived pervasiveness of these sources of failure has in turn led many in the field to reconsider the appropriateness of the invariance and the completeness of preferences (Shogren et al., 1994; Spash and Hanley, 1995), the independence of optimization (Marglin, 1963; Kahneman and Knetsch, 1992), and the fullness and relevance of knowledge conventions (Pigou, 1920; Norgaard, 1990) for the analysis of environmental and resource issues. Arguably the field has therefore displayed a lesser willingness than its parent discipline to protect theory from data.

Given that allocation system failures exist, the field perceives the second of its tasks to be measurement of the surpluses foregone due to these failures. A variety of clever observed behaviour techniques, for example, travel cost (Clawson, 1959), dual profit functions (Garcia et al., 1986), hedonics (Ridker and Henning, 1967; Freeman, 1971), household production (Becker, 1965), mathematical programming (Adams et al., 1982), have been developed. All rely upon specification of a complementary or substitution relation between a market good and the non-marketed, environmental good of interest. A stated behaviour method commonly called contingent valuation (Knetsch and Davis, 1966) has recently attracted wide interest among policy makers responsible for providing and protecting non-marketed environmental goods, though the meaning of the results of the technique in terms of the core behavioural assumptions of general economics remains open to considerable doubt (Diamond and Hausman, 1994; Hanemann, 1994). Insights from psychology have, however, proved fruitful in structuring and interpreting contingent valuation studies (for example, Kahneman and Knetsch, 1992).

Resource economists have also identified new types of surplus to measure. The most defensible in terms of economic theory are option value or the value of avoiding commitments that are costly to reverse (Weisbrod, 1964), quasi-option value or the value of maintaining opportunities to learn about the benefits and costs of avoiding possibly irreversible future states (Arrow and Fisher, 1974; Henry, 1974), bequest value or the value of contributing to the welfare of future generations (Cropper and Sussman, 1988), and existence or pure non-use value (Krutilla, 1967). Limited empirical work (for example, Schulze et al., 1983) indicates that these types of value can be a greater portion of the total value of environmental goods than is traditional use value. Dixit and Pindyck (1994), while drawing upon results in financial economics, have recently expanded understanding of the set of observed behaviour techniques available to assess option and quasi-option values, including land development (Capozza and Li, 1994). Controlled experiments designed to be incentive-compatible are increasingly used to inform and to assess the reliability of valuation work in the field (Cummings et al., 1995).

A third task for the resource economics research programme has been the design of allocation systems capable of realizing the foregone surpluses. The efficiency or incentive-compatibility properties of mandated effluent or ambient standards versus effluent charges (Kneese and Schulze, 1975), tradable rights (Crocker, 1966) or permits (Dales, 1968), and environmental bonds (Shogren et al., 1993) or liability (Kolstad et al., 1990) in the presence of asymmetric information between non-cooperating regulators and polluters (Segerson, 1988; Xepapadeas, 1991) now dominate the discussion. Much of the related empirical work is sophisticated in natural science as well as in economic terms (Russell and Spofford, 1977; Atkinson and Tietenberg, 1982). Game-theoretic approaches to understanding sufficient conditions for cooperative agreements about pollution problems also now frequently appear (Hoei, 1991; Barrett, 1992). Again, controlled experiments are increasingly used to gain empirical insights about the efficiency and distributional properties of alternative designs (Cason, 1995). A major
finding of all this design work is that single-price market devices are not the only or always the best ways to allocate environmental and natural resources. Both economic theory and empirical observation demonstrate that voluntary, cooperative non-market institutions built upon rules of access to and use of a resource held in common can be very effective at capturing surplus and pooling risks (Bromley, 1991).

Elicitation of the sources of and corrections for market, regulatory, and household failures, and the measurement of the associated foregone and potential surpluses, have been approached using the perspective of microeconomics. The fourth task that post-World War II resource economics has undertaken focuses on depletion, large macroeconomic-like questions about trends in the availability of environmental, biological and mineral resources and their effects upon economic growth. Starting with Barnett and Morse (1963), numerous studies assess the ability of the price system and of human inventiveness to overcome the diminishing returns principle of Malthus (1798) and Ricardo (1817). Because adaptive expectations rather than rational expectations appear to dominate the behaviours of extractive industries (Farzin, 1992; Pesaran, 1990), the validity of applying Hotelling (1931) principles to test the increasing scarcity hypothesis has been questioned (Eagan, 1987).

Treatments of the life support, amenity and waste disposal services of the natural environment as free in general economics studies of man-made capital formation are nevertheless shown to have led to exaggerated estimates of rates of growth in economies (Nordhaus and Tobin, 1972). In addition, the axis of the depletion discussion has shifted from the stand-alone service flows of individual environmental goods to a view of these goods as bundles of assets (Mohring and Boyd, 1971) that demand attention to the sequential and spatial patterns of their uses and abuses (Keeler et al., 1972; Forster, 1973). The result has been greatly increased attention to the joint products that the assets offer and to the impact of the often subtle connected global and ubiquitous local cumulative impacts of environmental change upon the ability of competitive but incomplete markets to sustain these offerings (Plourde, 1972; Dasgupta and Heal, 1979). These subtleties inspire increased use of simulation techniques to test analytical results and to gain insight about detailed structural responses to system perturbations (Deacon, 1993). There is controversy as to whether the economic scarcity of mineral and immobile biological resources has been increasing (Norgaard, 1990; Devarajan and Fisher, 1982). For other biological and environmental resources such as fisheries and water quality the consensus is that depletion governs (Smith and Krutilla, 1979), partly because of the stress that the extraction and consumption of mineral and immobile biological resources place upon them. However, limited empirical evidence shows an inverted U relation between pollution flows and economic growth whereby initial increases in pollution flows with growth are eventually offset by increased abatement effort at higher levels of development (Grossman and Krueger, 1995). The increasing scarcity discourse has generated a rapidly expanding analytical and empirical management literature dealing with intergenerational equity and efficiency (Solow, 1974; Hartwick, 1977) and thus conservation ethics (Page, 1977), accounting for resource depletion in macroeconomic indicators (Peskin, 1972), the double dividend fiscal implications of pollution and depletion taxes (Munasinghe and Cruz, 1994), the relationships between environmental life support and amenity depletion and economic growth (Voudsen, 1973; Daly, 1977), environmental quality and poverty (Dasgupta, 1993), and environmental quality and international trade (d'Arge and Kneese, 1972).

Starting with Boulding's (1966) application of the conservation of mass principle and Georgescu-Roegen's (1971) advocacy of greater economic attention to the entropy principle, resource economists have commonly used prior information from the natural sciences to restrict the dimensionality of their positive models of economy-environment interactions (Ayres, 1978; Clark, 1976), and to develop normative criteria other than consumer sovereignty for sustaining the potential of natural capital assets to contribute to well-being (Pezzey, 1986; Common and Perrings, 1992). Scholars who choose to make the reciprocities between ecological system functions and economic systems dominate their normative thinking now identify themselves as ecological economists. They propose that their view of ecological processes as a reciprocating part of economic activity (Norgaard, 1983), rather than as an independent background support upon which this activity feeds, distinguishes them from standard resource economics practice. Though the distinction has some validity for a general economics that centres upon exchange rather than resource transformations, it probably claims too much relative to the actual traditions of resource economics. After all, sustainability or risk aversion against environmental change, the badge of the ecological economics club, was a primary concern of Ciriacy-Wantrup (1952), Scott (1955), Solow (1974), Hartwick (1977), and even of Hicks (1936), the archetypical general economist. Though the ecological economists have demonstrated it under restricted conditions, these predecessors clearly suspected that the price system favoured by the current generation and its immediate progeny and the pace of human capital accumulation may be insufficient to sustain human well-being across generations.

Unfortunately the resource economics research programme has evolved in a setting of environmentalist scepticism, even outright hostility, toward its content and implications (for example, Anderson, 1993). At root, these
feathers stem from the nearly two centuries-old shallow-brained propensity of intellectuals to avoid reading economics and to complain, without reading, that its content and arguments correspond perfectly to commercial interests. With natural resources, the correspondence is reflected in the reluctance of environmentalists to grant that natural assets can be traded off against other entities that humans desire. The reluctance is encouraged by the inattention that ecological theory gives to the roles of human discretion in ecosystem behaviour. Environmental policy making has often manifested these feelings. Witness the neglect of economic analysis in environmental risk assessment practice in the United States, as if human choice plays no role in observed pollution exposures and damages. Policy has thus typically lagged far behind the findings and insights of the field until the pressure of events (rapidly escalating control costs, obvious rent dissipation, citizen resistance to bureaucratic rigidities) forces a reconsideration of the economic dimension. Recent political rhetoric about replacing command-and-control schemes of pollution control with economic incentives such as tradable rights is a prime example. Greater attention by the field to problems of providing operational guidelines for its findings would undoubtedly reduce the lag. Resource economics can no longer validly be viewed by practical people as a collection of 'empty boxes' (Clapham, 1922).

4. Conclusions
It is easy to be impressed with the depth and the breadth of knowledge that the serious environmental and resource economist must now command. This necessary knowledge spans the domain from the extremely practical to the highly abstract and general – from doing a cost–benefit analysis of a particular project to modelling dynamic economies with increasing returns and incomplete markets. Environmental and resource economics has done more than any other field to bring natural science and psychology into economics. Because of the significant role that institutional and property rights design issues play in environmental questions, the same assertion might be made about the law. This drive toward a multidisciplinary focus is caused by the frequent absence in resource settings of prices that bring together the laws of nature and rules of man relevant to the burden of scarcity. The focus suggests that many of the great discoveries in resource economics have yet to be made. All the veins of environmental and natural resource questions to which economics can be applied and from which economics can learn have not yet been mined or even discovered.

Nevertheless, one might readily question whether the substantial intellectual talents the field attracts are now being allocated in the most productive manner across its four self-elected tasks.

Practical matters of legal suits and bureaucratic rule making have caused some of the best minds in the field to turn inward toward technical economic minutiae associated with the humdrum everyday business of valuing site- and time-specific non-marketed environmental goods. Bigger at the margin but less commercialized questions about the sources of environmental problems, the institutional means to resolve them, and their intergenerational consequences have partly become the province of some natural scientists, especially ecologists, and general economists who choose to face outward. This recruitment of fresh talent is what will keep the field dynamic and continue to enrich its explanatory power and its normative punch.

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