The Early History of Environmental Economics

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Introduction

Environmental economics[1] is a relatively new field of specialization in economics: Many writers on the history of the subject, for example, Pearce (2002), trace its beginnings to the 1960s. While it is true that it was during the 1960s that the term "environmental economics" came to be used in the titles of books and articles, leading over time to the establishment of environmental economics journals, conferences and professional associations, the "early history" in the title of this article actually refers to the literature published prior to the 1960s. I believe that in this literature – going back more than two centuries - we can see the true beginnings of environmental economics proper. There are indeed a number of contributions from economists in the eighteenth, nineteenth, and early twentieth centuries that are relevant for the economic analysis of environmental problems, and my objective here is to extract some interesting perspectives from these writings. I make no claim to completely cover this early literature. This would be difficult to achieve with any survey but, especially in this case, because the literature that I examine was not considered at the time to be part of a separate and well-defined field.

Why should we as modern and forward-looking environmental economists take an interest in our early history? Some of us find the history of thought to be intrinsically interesting and need no further excuses to spend time studying it. For those who need a more instrumental justification for devoting attention to the older literature, one may argue that examining our early history can give us a broader perspective on current environmental problems and may also influence our research priorities in a positive way. I hope that this survey of the early literature will be helpful in both creating such a perspective and encouraging new and productive research in our field.

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[1]I include the economics of natural resources under the heading of environmental economics. Although it is true that some parts of natural resource economics do not have a clear focus on the environment, the two areas belong together, historically as well as scientifically.

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The remainder of the article is organized as follows. I begin by discussing the treatment of environmental problems in the work of Condorcet and the classical school, including Malthus, Ricardo, and in particular John Stuart Mill. The use of economics to solve practical problems of the environment is illustrated by some of the policy recommendations of Edwin Chadwick. I discuss Jevons' early analysis of natural resource scarcity before turning to the contributions of the marginalist school to the analysis of externalities and market failure, with particular attention to the contributions of Pigou. The formal analysis of the economics of natural and common property resources was begun by Marshall and continued by several writers, of whom Gordon and Hotelling are given special attention here. Toward the end of the article I consider the analysis of externalities and market failure in a general equilibrium setting by a number of theorists who took their inspiration from Paretian welfare economics. In the final section, I briefly discuss the emergence of modern environmental economics as being caused by both the growth of environmental problems and developments in economic theory.

An Eighteenth Century Forerunner

It is always difficult to choose a starting point for a survey of the history of ideas. If one searches hard, one will invariably find that every important writer has had some interesting forerunner or at least that there is some other author or authors that influenced him in a significant way. Nevertheless, one has to begin somewhere, and I begin in France with a writer that most economists know from a completely different field. The Marquis de Condorcet is famous chiefly for his formulation of the paradox of voting, which demonstrated, some two centuries before Kenneth Arrow's impossibility theorem (Arrow 1951), the possible irrationality of group decision making by majority voting. But thanks to the work of Emma Rothschild (2001) we now know that Condorcet's economic interests were much broader, and that they reflect an awareness of the link between economic activity and environmental quality.

In fact, Condorcet can be viewed as a pioneer in the use of externality arguments for policy analysis of environmental issues. In particular, he argued that although in principle private property rights should be respected, there is a case for government interference when the exercise of property rights by one individual violates the rights of others. Condorcet cited the example of an agricultural activity that "by corrupting the air, causes illnesses in neighboring homes."[2] Condorcet argued that in this case, the government would be justified in forbidding the activity that causes harm to the environment or in undertaking public works with a view to "restore the salubriousness of the air." A related example is the establishment of a factory that would reduce the local residents' air quality. In this case, Condorcet would view government action forbidding construction of the factory as a legitimate violation of the factory owners' property rights. It is interesting to note that Condorcet poses the policy choice as either allowing or forbidding the activity in question; at the time, the use of more subtle policy instruments such as taxes or subsidies had not yet emerged as practical policy options.

[2]This and the following quotations from Condorcet's 1776 book *Réflexions sur le commerce des blés* are taken from the translations in Rothschild (2001), 172–73, which provides further references to his work. Much of Condorcet's writing was not published during his lifetime and first appeared in print in *Oevres de Condorcet* in 1847–1849, more than half a century after his death in 1794.

Condorcet's recommendations of public interference with private property rights were based on a concern for social justice, not efficiency. It is unjust, he argued, for the value of individual properties to be reduced by economic activities of others that impair the quality of the environment.[3] However, Condorcet also argued that government interference should only occur when the harm to others can be clearly and convincingly documented; otherwise, this type of argument could be misused. A further point of interest is that Condorcet saw environmental pollution as a justification not only for the state to intervene in the market mechanism and restrict individual property rights but also for the government to encourage research aimed at developing cleaner technologies.

Since much of Condorcet's work remained unpublished and little known for a long time, he can hardly be considered to have been an important influence on the development of environmental economics. However, recent examinations of his writings, especially in the work of Rothschild (2001), indicate that recognition of the links between economic activity and environmental quality goes as far back as the end of the eighteenth century, which is much earlier than generally suggested in the environmental economics literature.

It is particularly striking that Condorcet's ideas appear to have been inspired by factual observation, not primarily by abstract reasoning. Such observations must also have been made at this time by others who thought systematically about economic and social questions, which may lead us to wonder why it took so long for these problems to be brought to the forefront of economics and social science. One reason may be that the problems were not viewed as being very important empirically. Moreover, economists in particular may have thought that at best these issues were on the periphery of their field. Indeed, such attitudes appear to have continued beyond the close of the eighteenth century.

The Classical School: From Smith to Mill

The classical school of economics includes the economists from Adam Smith to John Stuart Mill. Most members of the school were English and Scottish, although there were also some prominent followers in other countries (like Jean-Baptiste Say in France). Historians of economic thought have generally regarded this group as the founders of modern economics, although they too built on the work of previous thinkers and writers.

Regarding their basic microeconomic approach, the classical economists laid the foundations for the later neoclassical theory of price formation. In addition, Adam Smith is famous for his theory of the invisible hand, which claimed[4] that individuals who pursue their self-interest within the framework of competitive markets promote "the publick interest." This proposition spurred a long process of theoretical clarification that led to the modern theory of welfare economics. Moreover, Smith not only understood the ability of the market mechanism to allocate private goods efficiently; he also realized that there are goods for which the market

[3]This line of argument carries weight even today. For example, in discussions of the polluter pays principle many people find the argument that justice calls for polluters to pay for the damage they cause more persuasive than the argument that they should face incentives designed to promote efficiency.

[4]For a fuller discussion of the doctrine of the invisible hand and alternative interpretations of Smith's formulations see Sandmo (2011), chapter 3.

system does not function well and therefore have to be provided through government action, for example by

> "erecting and maintaining certain publick works and certain public institutions which it can never be for the interest of any individual, or small number of individuals to erect and maintain; because the profit would never repay the expence to any individual or small number of individuals, though it may frequently do much more than repay it to a great society." (Smith [1776] 1976, 687–88)

However, with the exception of passages such as this, the main works of the early classical economists, Adam Smith (1776) and David Ricardo (1817), contain no explicit reference to environmental issues in the context of the provision of public goods. Why is this? First, it is reasonable to assume that the process of industrialization and urbanization had still not progressed to the point where social thinkers had begun to recognize the magnitude of its effects on the physical environment. Moreover, environmental issues were not yet regarded as belonging to those aspects of social development that economists were expected to analyze.

Malthus: Theory of Population

There is, however, one member of the classical school whose fame rests on a theory in which the physical environment is a major constraint on economic development. Thomas Robert Malthus' theory of population (Malthus 1798) implies that the natural tendency of population to increase exponentially is constrained by decreasing returns in agriculture. Malthus argued that in the long run, population could only increase in step with the expansion of agricultural output. Moreover, the long run equilibrium level of wages would correspond to the subsistence level. This is because, if in the short run population were to increase at a faster pace than that which was consistent with the long-run sustainable level, forces would be unleashed to check it, such as

> "... unwholesome occupations, severe labour and exposure to the seasons, extreme poverty, bad nursing of children, great towns, excesses of all kinds, the whole train of common diseases and epidemics, wars, pestilence, plague, and famine." (Malthus [1798] 1992, 23)

This may not be environmental economics as we conceive of it today. Nevertheless, it does reflect an awareness of the feedback from the physical and man-made environment to human productivity and the standard of living, which clearly foreshadows present concerns. In addition to pronouncements of this kind, Malthus' general model of population dynamics contains a structure which has wider implications and inspired later economists to grapple with the issue of resource scarcity and economic development.

Ricardo: Resource Scarcity and Economic Growth

In his *Principles of Political Economy and Taxation* (1817), David Ricardo accepted Malthus' theory of population but emphasized a different aspect of the connection between the natural environment and the standard of living. His theory of land rent was based on the assumption that agricultural land varies in terms of fertility. More specifically, he argued that as the demand

for agricultural produce ("corn") expands, land of progressively lower fertility is brought into use, and thus the price of corn is determined by the cost of production on the least fertile land.[5] Because corn is of uniform quality, corn from the more fertile land will be sold at a price that exceeds its cost of production, and it is this excess that is the land rent. Ricardo argued that as the population and work force increase, the demand for corn will also increase, and so the extension of the margin of cultivation will lead to an increase in rental income. With a constant level of wage income this leads to a declining rate of profit. This will weaken the incentive to invest and put an end to the growth process in the form of the stationary state.

Ricardo (1817) also considered the extension of his theory of rent to the mining industry, but his discussion of this is not carried very far. After noting that the theories of rent that apply to mines and agriculture are essentially the same, he discusses the implications of the increasing cost of precious metals for the monetary standard, but he does not consider the growth implications of a possible scarcity of exhaustible resources.

As we know, the theory of rent regarding both agriculture and mining became of great importance for the future development of environmental economics. The same is true for the classical economists' notion of the stationary state, which was echoed much later in the heated debates concerning the limits to growth and the zero-growth society.

Mill: The Tasks of Government

The classical school of economics is usually considered as ending with John Stuart Mill. His *Principles of Political Economy* (1848) consolidated the classical approach while also breaking new ground in a number of ways, both analytically and by broadening the scope of economic analysis. An example of the latter is his discussion of the duties and limits of government, which reflects Mill's role as both a market liberal and social reformer. Having first distinguished between the necessary and optional tasks of government, Mill then argued that the former are in fact much more extensive than many economists are inclined to admit. The supporters of a minimal role for government argue that its necessary tasks are to protect the country against external enemies and to secure the life and property of its people. However, Mill argued that there are a number of additional tasks that are easily overlooked. For example, the role of the state in protecting ownership may be either narrowly or broadly interpreted. The narrow interpretation implies that the state should secure the right of each individual to what he himself has produced or legitimately acquired from others. But this is not the only kind of property that needs the protection of government. In a broader perspective:

> "[i]s there not the earth itself, its forests and waters, and all other natural riches, above and below the surface? These are the inheritance of the human race, and there must be regulations for the common enjoyment of it. What rights, and under what conditions, a person shall be allowed to exercise over any portion of this common inheritance cannot be left undecided. No function of government is less optional than the regulation of these things, or more completely involved in the idea of civilized society." (Mill [1848] 1965, 801)

[5]On the one hand, this conclusion is consistent with the classical cost of production theory of value. On the other hand, with its emphasis on increasing unit costs of production for agriculture as a whole, it predates the insights of the marginalist school whose breakthrough came several decades later.

In modern terminology, Mill emphasized the public good nature of the natural environment and pointed out that the management of this cannot be left to market forces and individual action.

However, Mill was not specific about the *form* that government action should take in this supplementary role in the allocation of resources. Despite his belief that public policy can make a positive contribution to environmental public goods, Mill remained skeptical of the state's ability to act in a more intelligent way than the market. Thus, he argued that government intervention cannot be justified solely because the *laissez-faire* allocation is imperfect; rather, there must be sufficient reason to believe that government action, though imperfect, will improve the outcome.

Although Mill did not attempt a systematic application of the tools of economic analysis to environmental problems, he did, on several occasions, express strong support for preserving the natural environment, for example, in his extensive correspondence with influential individuals and institutions. For example, in a letter to the secretary of the Commons Preservation Society in 1866, Mill said that

> "I have all my life been strongly impressed with the importance of preserving as much as possible of such free space for healthful exercise, & for the enjoyment of natural beauty as the growth of population and cultivation has still left to us. The desire to engross the whole surface of the earth in the mere production of the greatest possible quantity of food & the materials of manufacture, I consider to be founded on a mischievously narrow conception of the requirements of human nature." (Mill 1972, 1140–41)

In another letter, written a few years later, he commented on the desire by the Land and Labour League, an organization with strong ties to the labor movement, to convert large areas of waste land to farming:

> "I should be sorry to see the whole of these farmed out & given up to cultivation. I wish a great part of them to remain in their native wildness & natural beauty. There is little enough beauty in our common life, & we cannot afford to sacrifice what we have." (Mill 1972, 1651)

Incidentally, Mill was worried about the lack of political support for the preservation of the natural commons but remarked in a letter to one of his correspondents that

> "[w]omen's suffrage will help us in this as in so many other things, for women will be much more unwilling than men to submit to the expulsion of all beauty from common life." (Mill 1972, 1659)

Perspectives on the Classical Economists

This brief review of the writings of Mill and some of the other classical economists suggests that there was an early awareness of the environmental problems that modern industrial civilization was creating, as well as a realization that public policy, if carried out intelligently, could improve on the market outcome. However, the state of economic theory at the time made it difficult to pinpoint the sources of market failure and thus to identify the appropriate public policies for ensuring economic and social improvement.

Theory and Applications: Edwin Chadwick

The theoretical analysis of the classical economists regarding the workings of the market system was clearly based on a microeconomic analysis of how individuals could best pursue their own interest in the face of given market prices—in other words, on a theory of incentives. However, they were not particularly concerned about how this fundamental insight could be used for public sector decisions and for the implementation of social reform. One exception was Edwin Chadwick (1800–1890), a civil servant who was much influenced by the utilitarian philosopher Jeremy Bentham as well as John Stuart Mill. During his long and very active career as a public administrator Chadwick made a number of important contributions to the design of policy and pioneered both the creative design of incentive-based mechanisms and the use of empirical data. Since historians of economic thought have tended to focus on the development of pure theory, Chadwick has not received much attention in this literature. This has recently been rectified by the work of Robert B. Ekelund and co-authors, (e.g., Ekelund and Hébert [1997] and Ekelund and Price 2012). A vivid example of Chadwick's inventiveness in using incentives to improve the quality of public policy is his initiative regarding the transportation of British criminals to Australia. Initially, the captains of the vessels in charge of the transports were paid a flat fee per prisoner taken on board at the port of departure. When at Chadwick's suggestion the scheme was changed so that the captains were paid per prisoner who disembarked alive in Australia, the survival rate among the convicts increased from 40 percent to 98.5 percent. This story is both depressing and encouraging. It is depressing in its cynical depiction of the attitudes of the captains. At the same time it is encouraging in showing how a clear-thinking economist may design an incentive scheme that utilizes the desire for private financial gain to achieve an improvement which clearly benefits society.

One of the fields where Chadwick made a major contribution to public administration was public health and sanitation, and one area within this field that particularly concerned him was the funeral industry, or rather the two interrelated markets for funerals and burials. In a government report (Chadwick 1843), he argued that the market for funerals was characterized by an inefficient structure (mainly due to high information and search costs), which caused the price of funerals to be too high. The high price caused delays, which in turn led to a sanitation problem. The health damage from the delays in burials was exacerbated by the existence of widely dispersed and overcrowded private graveyards, which caused the spread of fever, typhus, and other diseases. Chadwick collected a very large amount of medical data to support his case and argued that funerals and burials should be a government responsibility but that they should be carried out by private undertakers, who would be selected through franchise bidding. The Board of Health would own and manage burial grounds, which were to be located outside the central metropolitan areas in order to eliminate the sanitation externalities.[6]

This is just one of the many examples of Chadwick's efforts to exploit private incentives for the common good in the face of externalities. Although he was not an economic theorist, his ability to utilize classical price theory to design incentives for environmental and social

[6]Chadwick's work on this issue is described in Ekelund and Ford (1997).

improvement is impressive and he ought to be recognized as a pioneer of environmental economics. Moreover, Chadwick's extensive use of empirical data to support his analysis and policy recommendations further confirms his important role in the history of our discipline.

Natural Resource Scarcity: Jevons and the Coal Question

Historians of economic thought generally focus on William Stanley Jevons as an economic theorist and a pioneer of neoclassical economic theory. This focus is clearly justified by the fact that his book *The Theory of Political Economy* (Jevons 1871) was one of the major contributions to the so-called marginalist revolution with its increased emphasis on the demand side of the economy and the use of mathematical methods. However, Jevons was as much an empirical economist as a theorist, and his empirical contributions reflect his early training in mathematics and the natural sciences. His first major empirical work was *The Coal Question* (Jevons 1865), which caused a great stir by predicting England's demise as an industrial nation through the depletion of its coal reserves. Although Jevons had been disappointed by the lack of interest in his attempt in the early 1860s to introduce the concept of marginal utility as the foundation for price theory and his advocacy of the use of mathematics in economics, he could not complain about the reception of *The Coal Question*. His gloomy prediction of the end of the era of economic progress in England caught the public imagination; it was discussed in Parliament, and Prime Minister William Gladstone invited him to a personal conference to discuss his ideas.

The Depletion of Coal Reserves

The main theme of *The Coal Question* was that England's economic development was bound up with exponential growth in industries that were dependent on coal as a source of energy. However, Jevons argued that coal could no longer be extracted at a speed that would allow this growth to continue, that the lack of coal would act as a brake on the country's economic growth, and that it was therefore necessary to rethink its national strategy. Jevons goes into great detail in building his case, including an extensive discussion of the cost of coal mining and its geological foundations. There are some references to economic theory, but the absence of formal theory is more remarkable than its use. There are no references to the formal theory of supply and demand and no attempts to use the theory of the allocation of resources over time, which Jevons was later to sketch in his *Theory of Political Economy* (1871). One reason for this might be that such a link between theory and application was not within his analytical reach; another likely explanation was that because the book was aimed at a broad public, the inclusion of formal theoretical reasoning would be misplaced.

It is interesting to note that Jevons explicitly links the present and future price of coal to the cost of extraction. While modern resource economists will have no difficulty in following him on this point, it is nevertheless remarkable that the author of *The Theory of Political Economy* should take this strong view of cost as the determinant of price. For in that book (as well as in his earlier work) Jevons was emphatic that marginal utility, not cost, is the basis for understanding price formation. A pioneer in pure theory, Jevons' grasp of its implications had still not reached the point where this new approach influenced his applied work to any significant degree.

Jevons and Malthus

From a broader environmental economics perspective the most interesting aspect of *The Coal Question* may be the connection Jevons made with Malthus' theory of population. He accepts the hypothesis that, in his own words, "living beings of the same nature and the same circumstances multiply in the same geometrical ratio"; this statement, he says, is self-evident once the meaning of the words is properly understood. He then argues that what is true of population is true of society more generally. That is, if the circumstances and character of the people are the same, then there will be a natural tendency for the economy to grow exponentially. But at this stage of the argument, he warns that we must be careful:

> "We are getting to the gist of the subject. Even if we do not change in inward character, yet the aggregate of our exterior circumstances, our *environment,* as Mr. Spencer expresses it, is usually changing." (Jevons [1865] 1965, 194)[7]

The emphasis (which is in the original) is an indication that at the time "environment" was a relatively new term, at least in an economic and social context.

The changing environment refers to the diminished supply of coal reserves, and the reduction is the result of both population growth and the increase in per capita consumption. Jevons discusses the applications of the Malthusian model to this issue and points out a difference between agriculture and mining that has major and serious implications:

> "A farm, however far pushed, will under proper cultivation continue to yield for ever a constant crop. But in a mine there is no reproduction; the produce once pushed to the utmost will soon begin to fail and sink towards zero. *So far, then, as our wealth and progress depend on the superior command of coal we must not only cease to progress as before – we must begin a retrograde career.*" (Jevons [1865] 1965, 201)

An interesting question that arises from Jevons' discussion of resource scarcity is obviously what possibilities there are for substituting other sources of energy for the vanishing coal reserves. On this point Jevons is a bit vague. He discusses the possible future role of electricity but finds it to be clearly inferior to coal. Speculating further, he points out that

> "[a]mong the residual possibilities of unforeseen events, it is just possible that some day the sunbeams may be collected, or that some source of energy now unknown may be detected. But such a discovery would simply destroy our peculiar industrial supremacy." (Jevons [1865] 1965, 190)

Jevons does not attempt to analyze the constraints on energy supply in a global context. Rather, he focuses on Britain's position–indeed mainly its *relative* position—in the world.

There has been a tendency in the literature to downplay Jevons' analysis of resource scarcity and to treat it as an unimportant and somewhat sensational piece of writing by an economist whose historical significance derives from his contribution to pure theory. However, I believe that this judgment is both too harsh and too narrow and that *The Coal Question* should be

[7]"Mr. Spencer" refers to Herbert Spencer (1820–1903), a philosopher who believed that biological laws should also be applied to the study of man and society.

regarded as a significant contribution to the early history of environmental and resource economics.

The Marginalist Revolution and the Environment

The marginalist revolution of the 1870s, with Jevons, Carl Menger, and Léon Walras as its main proponents, sought to improve on the economic theory of the classical economists in two main respects. The first was to generalize the theory of price formation, in particular to clarify the role of demand and its foundations in the theory of utility maximization. The second was to investigate the basis of Adam Smith's contention that competitive markets result in an allocation of resources that is in the public interest.

General Equilibrium Theory

The most prominent achievement of this first generation of marginalists was Walras' *Éléments d'économie politique pure* (Walras 1874–1877) in which he worked out the general equilibrium of a competitive market economy and demonstrated that it maximizes a notion of social utility which bears some resemblance to the concept of optimality which was later formulated by Vilfredo Pareto. However, neither Walras nor Jevons nor Menger used the competitive equilibrium model to derive conclusions about optimal policy in the case of market failure. This task was undertaken by later generations of marginalists.

The main contribution of Pareto's *Manuel d'économie politique* (Pareto 1909) was to prove that the conditions for the optimum allocation of resources which now bears his name are satisfied by the equations characterizing the competitive equilibrium in the absence of externalities. This finding was of great importance for later work on externalities in a general equilibrium setting, although Pareto himself did not focus on this issue.

Partial Equilibrium Theory and Externalities

At the same time that Walras and Pareto were working on general equilibrium theory, Alfred Marshall was developing partial equilibrium theory, particularly in his main work, *Principles of Economics* (Marshall 1890). Viewed from today's perspective, one of Marshall's great achievements was his formulation of the concept of externalities or, in his own words, external economies and diseconomies. Marshall's choice of words reflects his chief use of the concept, which was to explain a puzzle that he claimed to observe empirically, that is, that the long-run supply curve for a competitive industry was downward sloping. Since, under competitive conditions, the supply curve for the individual firm had to be upward sloping, the existence of a downward-sloping curve for the industry as a whole could be explained by positive cost externalities between firms, meaning that increased output by one firm leads to lower costs for others. But Marshall argued that the externalities could also go the other way, i.e. there could be external *dis*economies. An important implication of Marshall's analysis is that in the presence of externalities, the competitive equilibrium will no longer be socially efficient; using Marshall's terminology, the market equilibrium will no longer maximize the social surplus.

At this general level the concepts of external economies and diseconomies would appear to have little to do with environmental economics. However, one example of external

diseconomies that Marshall discusses in some detail and which is clearly relevant to the environment concerns fisheries. An individual firm in the fishing industry may experience constant returns to scale (i.e., two vessels will be able to catch twice as much fish as one). However, when many firms increase their number of vessels, the stock of fish declines, and vessels may have to travel further in order to catch the same amount as before. This means that the unit cost of fishing goes up, and because the private marginal cost of fishing is less than the social cost, individual firms have an incentive to push aggregate resource use beyond the social optimum (Marshall [1890] 1920, 166). It should be noted that Marshall's conclusion regarding this issue exhibits a degree of caution that was characteristic of his style of writing; the possibility of overfishing was being hotly debated at the time, and he clearly did not wish his illustration of a theoretical point to be interpreted as reflecting his personal position on this controversial issue. Nevertheless, the fisheries example was a pioneering effort to study the economics of a common property resource, and Marshall's conclusion about the tendency toward overexploitation had a significant impact on the more general approaches to this issue that followed.

Pigou and the Foundations of Environmental Economics

The theory of externalities was developed further by Marshall's successor at the University of Cambridge, Arthur C. Pigou. In *The Economics of Welfare* (1920) and *A Study in Public Finance* (1928), Pigou significantly extended the scope of the theory, particularly to include externalities in consumption.[8] He also analyzed how the choice of policies, particularly taxes, could improve the efficiency of resource allocation. In addition, he discussed the empirical measurement of environmental damage, a topic that was definitely novel in the academic literature, although it had been discussed by those engaged in public administration in this area, such as Chadwick. It is thus no exaggeration to claim that it was Pigou who laid the groundwork for the modern field of environmental economics.

Market Failure and Tax Policy

Pigou's analysis of market failure—to use a modern expression—is based on the distinction between what he calls private and social marginal net products. The social marginal net product is less than the private marginal net product if either the social marginal benefit is less than the private marginal benefit or the social marginal cost is higher than the private marginal cost. This will be the case if there are negative external effects, and Pigou cites several examples where this is likely to be the case. Thus, a factory that emits smoke that harms consumers—an example considered in some detail in *The Economics of Welfare*—imposes a cost on the community in excess of that which appears in its private accounts of revenues and costs,

> "... for this smoke in large towns inflicts a heavy uncharged loss on the community, in injury to buildings and vegetables, expenses for washing clothes and cleaning rooms, expenses for the provision of extra artificial lights, and in many other ways." (Pigou [1920] 1952, 184)

[8]In fact, Pigou began this analysis in his *Wealth and Welfare* (Pigou 1912), a book that may be considered to be an earlier version of *The Economics of Welfare*.

This means that the factory's private marginal cost is less than the social marginal cost. Because it implicitly underestimates the social cost, the factory has an incentive to expand its activities beyond the point where the marginal social benefit and cost are equal. This market failure can be corrected by tax policy:

> "When competition rules and social and private net product at the margin diverge, it is theoretically possible to put matters right by the imposition of a tax or the grant of a subsidy." (Pigou [1920] 1952, 381)

In his *Study in Public Finance* (1928), Pigou elaborates on this statement to claim that, when "maladjustments" exist,

> "it is always possible, on the assumption that no administrative costs are involved, to correct them by imposing appropriate rates of tax on resources employed in uses that tend to be pushed too far and employing the proceeds to provide bounties, at appropriate rates, on uses of the opposite class." (Pigou [1928] 1947, 99)[9]

Other Policy Options

Pigou did not regard taxes and subsidies as the only policy options for addressing environmental problems. He also pointed out that outright prohibition of the production or consumption of some items might sometimes be in order, and he suggested that his proposals might need to be modified when applied under non-competitive conditions. It is interesting to note that Pigou did not consider the establishment of property rights in environmental resources and the use of tradable permits to solve externality problems; the analysis of these issues occurred during the modern phase of environmental economics, beginning in the 1960s.[10] Given Pigou's background in the field of public finance, it is understandable that he focused on tax-subsidy schemes.

Pigou also warned against moving too hastily from theoretical propositions to specific policy proposals:

> "It is not sufficient to contrast the imperfect adjustments of unfettered private enterprise with the best adjustment that economists in their studies can imagine. For we cannot expect that any public authority will attain, or will even wholeheartedly seek, that ideal. Such authorities are liable alike to ignorance, to sectional pressure and to personal corruption by private interest." (Pigou [1920] 1952, 332)

This warning mirrors the attitude expressed by John Stuart Mill several decades earlier and also foreshadows the subsequent criticism by the public choice school of the allegedly naive

[9]The last part of this quote is a bit puzzling. It seems to suggest that tax collections and subsidy payments should somehow be in balance, whereas the main point is clearly to create the right incentives. Pigou may have been trying to abstract from the second best difficulties that would arise if the net proceeds of the tax/subsidy scheme had to be distributed or collected in a distortionary manner.

[10]One key source of inspiration for these later developments was the article by Coase (1960) which argued that in some situations of market failure individual agents may have private incentives to internalize the externality, so that public interference, for example, in the form of Pigouvian taxes would be superfluous. For a discussion of the influence of the so-called Coase Theorem on the later development of environmental economics, see Medema (2014).

applications of welfare economics to the design of economic policy.[11] Whether Pigou's cautionary words were sufficiently heeded by his successors in environmental economics and public finance is a matter for debate. My personal view is that Pigou's approach of combining his analysis of optimal policy with a realistic attitude toward the possibility of its political implementation is one that is shared by most of those who have worked in this tradition, and that much of the public choice criticism in this respect has been excessive.

Empirical Issues

Pigou also discussed possible empirical methods for assessing the benefits of environmental improvement policies. He did not make any original contributions in this area, but his examples of actual empirical investigations provide a guide to his thinking on the subject. To my mind, the most interesting example is Pigou's description of "a valuable investigation" carried out by the Manchester Air Pollution Advisory Board in 1918 (Pigou [1920] 1952, 185n.), which illustrates his argument about the environmental costs of factory smoke. The investigation compared the costs of weekly washing in the smoky town of Manchester with the clean town of Harrogate. Based on cost data for 100 working-class households in each town, it was found that the extra cost per household in Manchester was 7½ pence per week. The population of Manchester was three quarters of a million, and the cost of factory smoke to the city as a whole was estimated to be more than £290,000 per year. This was clearly a cautious estimate; it assumed, for example, that the cost was no greater to the middle class than to the working class, and this, as the Advisory Board pointed out, was "a considerable under-statement." In addition, the estimate was for only one of the components in Pigou's list of damages of factory smoke. His reason for citing this estimate (with obvious approval) must therefore have been mainly methodological; it demonstrated how one could go about using empirical data to estimate the costs of environmental damages.

Pigou also cites examples of positive environmental externalities where

> "... private marginal net product falls short of marginal social net product, because incidental services are performed to third parties from whom it is technically difficult to exact payment."

A case in point, which is of particular interest to modern environmental economists, concerns

> "... resources devoted to afforestation, since the beneficial effect on climate often extends beyond the borders of the estates owned by the person responsible for the forest." (Pigou [1920] 1952, 184)

This example mirrors the current debate about using afforestation as an instrument for global climate policy. More specifically, because national governments, as the "owners" of their territories, do not reap the full climate benefits from afforestation, global welfare maximization calls for subsidies to afforestation by national governments. The form such subsidies should take is one of the issues being considered in present-day discussions of global climate policy.

[11]For an early statement of this criticism, see Buchanan (1962).

Clearly, Pigou is a towering figure in the early history of our field. He developed Marshall's theory of externalities into the central analytical concept for understanding market failure in the presence of environmental externalities. He demonstrated how taxes and subsidies could be used to improve the allocation of resources in a competitive economy, and he suggested methods of empirical measurement that point forward to modern benefit-cost analysis.

The Emergence of Natural Resource Economics

It is in fact quite hard to pinpoint the actual beginning of natural resource economics. The frame of reference for the early classical economists in the late eighteenth century was a society that was still primarily based on agriculture, and the productivity of land therefore played a prominent role in the economics of Adam Smith and his predecessors. In Malthus' theory (Malthus 1798), agricultural productivity played a central role in his predictions of the population's future standard of living. Some decades later, Jevons (1865) emphasized the scarcity of a nonrenewable resource (coal) as a constraint on the development of the British economy, while Alfred Marshall (1890) identified the possible inefficiencies that could arise through competitive exploitation of a common property resource. The decades that followed saw the development of economic analysis in relation to both renewable and exhaustible resources. I will focus my remarks here on a few landmarks in the history of natural resource economics.[12]

Fisheries as a Common Property Resource

It took some time for other economists to follow up on Marshall's interest in fisheries as a common property resource. In fact, in the following decades it was biologists rather than economists who expressed concern that the organization of the fishing industry could lead to an outcome that was suboptimal from the point of view of society as a whole. The contribution that brought fisheries to the attention of the broader economics profession was the article by Gordon (1954), which described the structure of the fishing industry, constructed a formal economic model of biological and economic equilibrium, and derived conclusions for the design of economic policy. In Gordon's model, fishermen have free access to one or more fishing stocks and the marginal cost of fishing effort is assumed to be constant. From society's point of view, the optimal fishing effort is the level where the value of the marginal productivity equals the unit cost. However, with free access to the common property resource, the equilibrium will be where the value of the *average* productivity is equal to the unit cost. Because average productivity is greater than marginal productivity, the level of fishing effort will be too high. In Gordon's words,

> "... the rent which the intramarginal grounds are capable of yielding is dissipated through misallocation of fishing effort."

Gordon elaborated on this conclusion:

> "This is why fishermen are not wealthy, despite the fact that the fishery resources of the sea are the richest and most indestructible available to man. By and large, the

[12]For more detailed accounts of the history of this branch of economic theory, see Robinson (1989) and Barbier (1989).

> only fisherman who becomes rich is one who makes a lucky catch or one who participates in a fishery that is put under a form of social control that turns the open resource into property rights." (Gordon 1954, 132)

Gordon's article became extremely influential, particularly in fisheries economics but also in the broader field of the economics of common-property resources. From the point of view of the history of economic thought, it is interesting to note that many of Gordon's results had already been presented by the Danish economist Jens Warming (1911). However, Warming's article was published in Danish and thus failed to reach an audience beyond the Nordic countries, and his other efforts to present his theory to a wider international audience were also unsuccessful.[13]

The Economics of Exhaustible Resources

We have seen that Jevons (1865) was concerned about the consequences of the exhaustion of Britain's coal resources. Today, we might wonder why he did not take up the challenge of analyzing the optimal time pattern of exhaustion. One obvious explanation is that the theoretical tools required had not yet been developed, although only 6 years after publication of *The Coal Question* Jevons himself sketched the principles of utility maximization over time. Some early efforts to analyze this problem by the use of economic theory did occur during the next few decades, as for example in Gray (1914), which analyzed the problem of exhaustion on the basis of Ricardo's (1817) theory of rent.

However, the great leap forward in this area was in 1931 with the publication of Harold Hotelling's "The economics of exhaustible resources" (Hotelling 1931). Hotelling notes that the world's diminishing reserves of minerals, forests (sic) and other exhaustible resources have led to demands for the regulation of their exploitation—as John Stuart Mill (1848) had indeed called for almost a century earlier. As background to his theoretical analysis, Hotelling points out that

> "[the] feeling that these products are now too cheap for the good of future generations, that they are being selfishly exploited at too rapid a rate, and that in consequence of their excessive cheapness they are being produced and consumed wastefully has given rise to the conservation movement." (Hotelling 1931, 137)

On the other hand, he argues, it is well known that some of the supply of these resources is controlled by monopolies and generally accepted that monopolies restrict output below the social optimum. This view would appear to contradict the feelings prevalent in the conservation movement that resources are being exhausted too rapidly from society's point of view. To clarify this issue, there is a need for a more rigorous theoretical approach that moves beyond the framework of the static theory of optimal resource allocation. Hotelling argued that the analysis

[13]Warming's article was translated into English by Andersen (1983). Warming's work on fisheries economics is described in an interesting article by Topp (2008), which also contains a biographical sketch. An important feature of Warming's work was that he analyzed the use of a competitive market for quotas as a means of bringing about optimal resource use in the fisheries.

of optimal resource extraction must employ the most advanced mathematical tools of dynamic optimization theory. Indeed

> "[problems] of exhaustible assets cannot avoid the calculus of variations, including even the most recent researches in this branch of mathematics." (Hotelling 1931, 140)

Hotelling's Rule

The most famous result to come out of Hotelling's applications of the calculus of variation is his "rule" that under perfect competition the net price of a natural resource must grow at the rate of interest. He compared this equilibrium condition to the result derived from social welfare maximization (assuming that the welfare function took the form of time-additive discounted utility) and showed that the competitive equilibrium satisfied the optimality condition. Hotelling went on to examine a number of extensions of the model that would arguably move it closer to real-world conditions (such as monopoly resource ownership), and he studied the implications of the model for economic policy.

Altogether, Hotelling's "The economics of exhaustible resources" represents a major step forward in natural resource economics. Given its advanced mathematics, it may have been too far ahead of its time to have had a significant impact on economic policy when it was first published. Moreover, in the 1930s, other priorities were at the forefront of policy debates; Keynesian macroeconomics drew more attention from the profession than the economics of natural resources. However, with increased concern about resource scarcity in the 1970s, Hotelling's contribution received renewed attention from an economics profession that was now better prepared to consider policy analysis that was couched in the complex language of the calculus of variations.

Paretian Welfare Economics and Externalities

Pareto's work became more widely known in the mid-twentieth century and began to be explored and extended by some of the most prominent theorists of the time, notably Samuelson (1947), Lange (1942), Little (1950), and Graaf (1957). However, reading these contributions from the perspective of modern environmental economics one is struck by the fact that externalities occupy a very insignificant place in them; externalities as a source of market failure was evidently not considered to be a central element of welfare theory. On a related point, the typical exposition of welfare economics at the time had much to say about the marginal conditions required for an optimum (e.g., the equality of the marginal rates of substitution and transformation) but little to say about the marginal conditions that emerge from utility and profit maximization in a competitive equilibrium.[14] It is clear, however, that it is in the comparison of these two sets of marginal conditions and in the analysis of the cases when "prices are wrong" that we find the starting point for the analysis of market failure. Another notable feature of the welfare economics of the mid-twentieth century is that in cases

[14]In fact, Samuelson's justly famous chapter on welfare economics in his *Foundations* (Samuelson 1947) makes no mention of market prices and individual optimization.

where externalities and prices are actually being treated explicitly, the examples that are chosen to illustrate market failure (e.g., the two agent case of the apple grower and honey-producer in Meade [1952]), suggest that these are not important issues of concern for a modern industrial society.

A contribution that is significantly different in these respects is the article by Bator (1958), which explicitly links externalities to the failure of the competitive price system to capture all the costs and benefits that are relevant for a socially optimal allocation of resources. In addition, Bator introduces a separate category of externalities that had not been identified by previous writers, that is, the public goods type of externalities that could be related to the work of Samuelson (1954). Writing just a few years before the birth of modern environmental economics, Bator did not explicitly link this category to environmental externalities; he also failed to explore the distinction between private goods with externalities on the one hand and pure public goods on the other.

The Theory of Public Goods

The theory of public goods as first presented in the framework of welfare economics in Samuelson (1954) is of obvious relevance for environmental economics. The examples of unspoiled natural beauty and unwholesome factory smoke, as discussed by Mill (1848, 1972) and Pigou (1920), respectively, fit directly into this framework, as do our present-day concerns about biological diversity and global warming. Environmental benefit-cost analysis is the practical application of the fundamental ideas in the theory of public goods. Moreover, the optimality formula for the efficient provision of public goods—which requires that the sum of their marginal benefits equal their marginal cost—is reflected in the applied methodology of environmental project analysis.

However, Samuelson's analysis was limited to the case of pure public goods, and Bator's discussion was along the same lines. In this case, there is no conceptual distinction between individual and total consumption, and the individual agent has no—or at least extremely weak—incentives to provide a good whose benefits accrue to a large number of individuals but whose costs are borne solely by the individual agent. In the case of private goods with externalities, there is a positive private incentive to consume or produce the good in question. However, the individual has no incentive to take account of the additional costs and benefits, be they positive or negative, that arise for all other individuals in the community. Hence, there is the tendency for goods with negative externalities to be produced in an amount that exceeds the social optimum, while goods with positive external effects will be underprovided. This type of case received a lot more attention during the 1960s and after as the separate field of environmental economics developed. By modeling market failure in regard to the environment as a case where private goods production or consumption generates public goods type externalities, it can be shown that the Samuelson sum of the marginal rates of substitution measures not only the benefits from public goods provision, but also the benefits generated by appropriately leveled Pigouvian taxes that reduce harmful externalities.[15]

Thus, when environmental economics first emerged as a separate subdiscipline, a consistent framework for the analysis of market failure and corrective policies already existed. The further

[15]This point is made explicitly in Sandmo (1975).

development of welfare economics was marked by the emergence of second-best tax analysis, which, among other things, led to the literature on the double dividend. This issue is a concern of present-day environmental economics and thus moves us rather far from our field's early history. Nevertheless, it is important to emphasize that the theory of public goods and externalities has shown itself to be remarkably robust in its applications to environmental problems, gradually ascending from the local level of apples and bees to the global problem of climate change, "the greatest market failure the world has ever seen" (Stern 2007).

Environmental Economics and Public Finance

At this point, a comment may be in order regarding the relationship between environmental economics and public finance or public economics. Environmental taxation was discussed by Pigou in the 1920s and explicitly linked to public economics issues in his *Study in Public Finance* (Pigou 1928). But the relationship between environmental economics and public finance received relatively little attention in the academic literature in the following decades. One striking example of this neglect is Musgrave's famous treatise *The Theory of Public Finance* (1959), which summed up the status of the field at the end of the 1950s. Musgrave devotes little more than a paragraph to Pigouvian taxation, which does not even mention the environmental perspective (Musgrave 1959, 115). Even more puzzling, the paragraph appears in a chapter entitled "The ability-to-pay approach." This is in sharp contrast to the situation today, where environmental taxation and benefit-cost analysis are common and, in fact, central themes for both public finance and environmental economics.

The study of optimal environmental taxation and benefit-cost analysis applies welfare economics to public policy issues. The Paretian approach to welfare economics derives conditions for social efficiency and welfare from individual preference orderings or utilities. However, this approach may become problematic when it comes to examining the effects of consumption or production decisions on individuals when the consequences are hidden from most people, acting in their capacity as individual consumers and producers without specialized scientific information about the consequences of their private choices. The philosopher and economist Henry Sidgwick noted early on that such cases may call for deviations from the principle of consumer sovereignty. In his *Principles of Political Economy* (1887), Sidgwick pointed out that governments did in fact try to protect their citizens from making unwise choices concerning, for example, unhealthy or diseased food, unqualified physicians, and hazardous industrial work processes. In Sidgwick's view, consumer sovereignty, which he describes as "the fundamental assumption on which the economic rule of *laisser faire* partly rests," should only be accepted as "a handy though rough rule of practical statesmanship" from which exceptions should be allowed in special cases. This view has been reflected in many subsequent discussions of environmental problems, most notably, perhaps, in the current debate about global warming.[16]

Concluding Remarks

This has been a very selective survey of the early history of environmental economics, and it is fair to ask whether we can conclude that environmental economics even has an interesting past

[16]Banzhaf (2011) provides an interesting historical discussion of this issue.

prior to the 1960s. My own conclusion—which should come as no surprise—is that it does. Clearly, our discipline has much to learn from the early writings on environmental issues in a more specific sense, and also from the dependence of the growth of environmental economics on the more general development of economic theory and methods.

What explains the evolution of environmental economics from its early history of scattered contributions on a diversity of topics to a fully developed field of specialization in the post-World War II period? This is a big and complex question that cannot be fully answered here. On the one hand, one could cite the growth of environmental problems arising from increasing industrialization, energy use, and the pressure of population. On the other hand, one could also argue that increasing standards of living, particularly in the industrialized world, have led to an increased demand for environmental quality; that is, the appreciation of environmental goods is income elastic. The interactions between these two sets of factors might go a long way toward explaining the increased attention to environmental issues in economics.

However, this type of explanation is unlikely to be wholly satisfactory. It took a long time for economists to start paying attention to environmental issues, even though environmental problems like those relating to sanitation and public health must have already been pressing at the early stages of the industrial revolution. One of the reasons for this lack of attention among economists at the time is likely the widely held view that environmental quality was not a core issue of economics as a discipline. Another reason for the delay in focusing on environmental problems must certainly be that it took a long time for economists to develop the theoretical concepts required to analyze problems of market failure related to the environment.

Thus, the transition to the modern field of environmental economics in the 1960s may have started with the realization in the economics profession that its tools of analysis had finally reached the stage where they were adequate to the challenges posed by environmental deterioration. If this view is accepted, then the transition is an interesting example of what Tjalling Koopmans (1957) described as the "interaction of tools and problems in economics." As he put it, "The solution of important problems may be delayed because the requisite tools are not perceived. Or the availability of certain tools may lead to an awareness of problems, important or not, that can be solved with their help" (Koopmans 1957, 170). This perspective offers a promising approach to further examination of the history of environmental economics.

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