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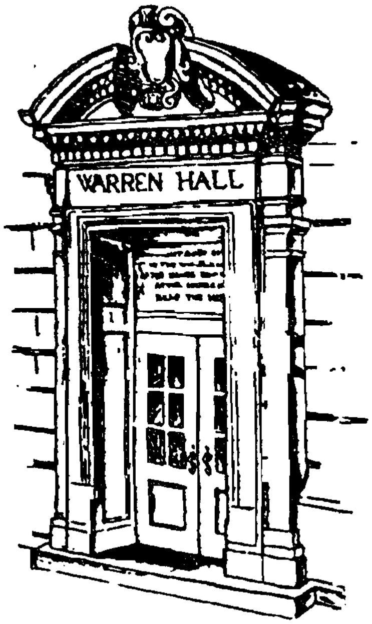


# Working Paper

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# REDIRECTING ENERGY POLICY IN THE U.S.A. TO ADDRESS GLOBAL WARMING

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# Redirecting Energy Policy in the U.S.A. to Address Global Warming

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## Abstract

This paper reviews the reasons why many environmental economists are skeptical about the optimism of most mainstream economists over the current low prices for energy and the associated high growth rates of consumption. The conclusion is that energy is different from other factors of production because 1) global warming places an environmental limit on the rate at which fossil fuels should be used, and 2) nuclear power no longer provides an acceptable new source of inexpensive energy to replace fossil fuels. Limiting the consumption of fuels has important implications for economic equity among nations, and replacing fossil fuels with renewable sources of energy has important implications for how the profits from producing fossil fuels are spent.

The USA is the major current source of greenhouse gasses, with China likely to become the major source within a generation. Nevertheless, neither of these countries is taking leadership in addressing either the equity or the environmental problems of global warming. This paper argues that the widespread reliance on competitive market forces to manage the rates of consumption of fossil fuels is inappropriate. The standard criterion from economic theory, developed by Hotelling, focuses on the profit from producing fossil fuels above the extraction costs. An alternative theory is proposed which follows from Marshall's concept of taking "stores from nature's storehouse." Under this principle, the focus is on the difference between the cost of a backup source of energy and the costs of extraction, which is generally much higher than Hotelling's profit. Current energy policy uses most of this Marshallian rent to encourage high rates of consumption through charging low prices for energy, rather than to develop reliable and inexpensive sources of renewable energy to replace fossil fuels or to improve energy efficiency.

Given the lack of commitment to address global warming in the USA and China, an indirect approach is proposed, namely to make a commitment to improve air quality in cities throughout the world. Compared to addressing global warming directly, such a policy would 1) make it easier to build public support because the health benefits are more direct than they are from reducing greenhouse gases, and 2) lead to lower emissions of greenhouse gases by increasing energy efficiency for residential, commercial and, most importantly, transportation purposes.

# REDIRECTING ENERGY POLICY IN THE U.S.A. TO ADDRESS GLOBAL WARMING

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## 1. INTRODUCTION

Environmentalists are becoming increasingly skeptical about the validity of recommendations made by economists about environmental issues. Typically, economists believe that unbounded economic growth can continue well into the next century, and that markets (when free from artificial distortions) are efficient mechanisms for governing the use of natural resources such as fossil fuels. Most environmentalists would challenge these assertions. While problems stemming from market failures are recognized by economists, they also believe that solutions to these problems can and will be found. There is no need at the present time to reformulate the established methods of doing economic analysis. Marginal corrections to the existing system are all that is required. The primary objective of this paper is to question this conclusion by considering how energy policy in the U.S.A. is dealing with the problem of global warming.

Four standard limitations of markets are discussed in Section 2, and the optimism about continued economic growth expressed by economists is based on a belief that governments will be able to correct these deficiencies in the performance of markets. Environmentalists, on the other hand, believe that the effectiveness of governments in modifying markets is decreasing because the influence of competitive markets in the global economy is expanding.

The focus in Section 3 is on energy and the history of concerns about running out of supplies of different fuels. High discount rates and omitted environmental costs both contribute to keeping energy prices low in the short-run and to reducing the incentives for developing alternative sources of energy. Since there is growing scientific evidence that global warming places a constraint on the rate at which fossil fuels should be used, there is an increase in the social premium for the development of "backstop" technologies and for more restraint in the use of fossil fuels. In spite of this evidence, current forecasts of emissions of greenhouse gases, presented in Section 4, show substantial increases in all regions of the world except the former Soviet Union and Eastern Europe.

Most of the forecasted growth in energy use will be in low and middle income countries. Assuming that a policy for stabilizing global emissions of greenhouse gases is desirable, considerations of equity imply that emissions should be reduced in high income countries to compensate for some growth in low income countries. This is the basic predicament for high income countries that led to the agreement at the United Nations Earth Summit in 1992 to stabilize emissions at 1990 levels. Since emissions in the U.S.A. currently account for over 20 percent of the global emissions of greenhouse gases from fossil fuels, it is argued that the U.S.A. must take leadership in the formation of policy for global warming. Without a major redirection of energy policy in the U.S.A., it is highly unlikely that other countries will be willing to make effective changes.

Placing environmental limits on emissions of greenhouse gases will require widespread increases in energy efficiency. For high income countries, it will also be necessary to have public support for making sacrifices that benefit low income countries. Current evidence in the U.S.A. is that income inequities are growing within the country, and that the public's support of government welfare programs for redistributing income is shrinking. The conclusion in Section 4 is that the government will not be able to build political support in the U.S.A. for effective policies to deal with global warming unless public attitudes to energy and equity change.

The objective of Section 5 is to develop an economic explanation of why the views of economists and environmentalists about energy are so different. It is argued that Hotelling's (1931) rule for managing the extraction of a non-renewable resource underestimates the true value of fossil fuels. Even if the market discount rate equaled the social discount rate, the size of Hotelling's scarcity premium is small until the remaining stock of a resource is low. For most of the economic life of a resource, the price is effectively determined by the direct costs of production. An alternative approach is proposed using Marshall's (1920) concept of nature's stored up treasures. This approach places the focus on the cost of replacing fossil fuels, and raises the question of whether the rents from fossil fuels are being used wisely under current policies.

The final section summarizes the evidence about current energy policy in the U.S.A. Given public attitudes, it is unlikely that effective policies for addressing global warming will be implemented. For this reason, a series of alternative strategies are presented that address the problem of global warming indirectly. These include improving air quality in urban areas and forming a partnership for improving energy efficiency with a low income country such as China.

## 2. FOUR CHRONIC PROBLEMS

In any textbook on resource economics, limits in the ability of markets to reach socially efficient solutions are recognized. The issue is how seriously are these limits taken in actual practice and what measures are being taken to correct them. Attitudes among economists on this issue vary. On the one hand, a leading neoclassical economist, Robert Solow (1992), is relatively optimistic about the current situation. His opening remarks in a paper presented to Resources for the Future on non-renewable resources state "You may be relieved to know that this talk will not be a harangue about the intrinsic incompatibility of economic growth and concern for the natural environment. Nor will it be a plea for the strict conservation of non-renewable resources ....." (Solow, p. 5). In contrast, Herman Daly and John Cobb (1989) consider that the corrective measures proposed by economists "are ad hoc corrections introduced as needed to save appearances, like the epicycles of Ptolemaic astronomy" (Daly and Cobb, p. 37). A major reason for these different attitudes is the amount of faith that they have in the future ability of governments to solve economic and environmental problems. The optimism of economists comes from a belief that appropriate corrections to markets could be made, and the pessimism of skeptics comes from a belief that corrections won't be made. The evidence about global warming, presented in the next two sections, suggests that the skeptics are correct for this particular environmental problem.

In Solow's paper, four limitations of competitive markets are identified. The differences between Solow's optimism over the ability to overcome these limitations and the concerns raised by Daly and Cobb are reviewed in the following discussion to provide a framework for evaluating energy policy. The framework also helps to identify the reasons why environmentalists believe that economists undervalue the importance of energy.

## Discounting the Future

Many environmentalists and economists recognize the fact that market rates of discount are typically too high to value events in the future correctly from a social perspective. For example, Solow states "To make conservation an interesting proposition at all, the common discount rate should not be too large" (Solow, p. 10). Uncertainty about the future and concerns about receiving returns from investments increase rates of discount, and may also discourage exploration for new reserves of non-renewable resources (Dasgupta and Heal (1979)). Hence the problem for resource economists in practice is to determine how the high market rates of discount can be lowered when alternative investments or policies are evaluated. For some projects, governments or non-government organizations, such as The World Bank (1992), make the decisions and can use social rates of discount in their calculations. Nevertheless, it is unlikely that this type of argument would influence decisions made by an oil company operating an oil-field in a politically unstable region. Getting a financial return on the investment as quickly as possible would be the primary goal. At the present time, it appears that more reliance will be placed on market forces for making economic decisions given widespread public concern about high rates of taxation, the recent collapse of the Soviet system of planned economies, the growing influence of international corporations, and the increasing reliance on competitive markets to make economic choices. Consequently, the problems associated with high rates of discount will not be resolved in a global economy in which international markets are the dominant force behind economic decisions.

It should be noted that many economic decisions are made without government interventions using implicit discount rates that are low. This can happen for any investment that does not require commercial financing. Obvious examples are the investments that parents make in educating their children. These investments may involve the allocation of time by the parents as well as financial expenditures. In spite of the importance of these types of investments, most economists would treat them as items of consumption by the parents.

The concept of family decisions can be extended to include economic production and community activities. One could argue, for example, that one reason for supporting family farms is that these farmers may be more willing to make long-term investments in establishing environmentally sound production techniques and reducing damage such as soil erosion. It seems highly likely that the issue of discounting the future too fast underlies the proposal, made by Daly and Cobb (Chapter 11), to rely more on local communities and less on markets for making economic decisions.

Conventional economic models are limited by not considering how people invest their resources outside market activities. Spending time with children, repairing one's home, working on a community project and looking after an elder relative are all real investments of time and money. Since these types of decisions can ignore the high discount rates that exist in the market, the future tends to be taken more seriously when these decisions are made. Hence, it is a sign of serious economic collapse when the options facing people are so limited or their attitudes are so myopic that they destroy their local environment. One can hypothesize that a viable community implicitly uses a low or zero social rate of discount, and therefore, that long-term environmental issues are considered seriously. Given the expanding role of competitive markets in the production of fossil fuels, however, the important implication is that relatively high rates of discount will be used in the energy industry. Governments can offset the effects of high discount rates, to some extent, by taxing the use of fossil fuels, which leads to the next problem of environmental externalities.

## Incorporating Environmental Externalities

The prices paid for commodities in a typical market economy do not include the social costs of many types of environmental damage. These externalities have been discussed in the economic literature for over fifty years. Ignoring these costs leads to market prices that are lower than social prices, and as a result, levels of consumption are too high from a social perspective. Generally, the imposition of Pigouvian taxes is proposed as a solution by economists (e.g. see Pearce and Turner (1990), Chapters 4 and 5). These taxes would increase market prices, lower levels of consumption and, if appropriate, encourage polluters to install control equipment to reduce environmental damage.

In the absence of Pigouvian taxes for environmental damage, governments can impose regulations on sources of pollution and levels of safety for the public. Although Coase (1988) (Chapter 5) has argued that markets can solve environmental problems efficiently without government intervention or Pigouvian taxes, the conditions for this to happen are limited. In many situations, an issue ignored by Coase, transaction costs, is a dominant factor. For the pollution associated with burning fossil fuels that contributes to urban smog or global warming, for example, the number of sources of pollution and the number of people affected are both very large. Transaction costs for solving the problem of urban smog through market forces would be prohibitively high. The ongoing legal battles over the tobacco industry are a good illustration of how difficult it is to assign the blame for adverse health effects to a particular source of pollution. For problems such as urban smog and global warming, the relationships between sources of pollution and the different types of damage are even more complicated. Although the simple bargaining proposed by Coase could solve the problem of sparks from a steam train setting fire to a farmer's field, it would not be effective for global warming.

The prices of natural resources should reflect the correct social discounting of the future as well as incorporate external costs. Solow states that it is "obvious that every day market prices can make no claim to embody that kind of foreknowledge" (Solow, p. 16), but the increasing competition in global markets will not correct these types of deficiencies in pricing. International competition will probably have an adverse effect on existing environmental standards and worker safety because there is no global equivalent to the control that national governments have over national economies. Furthermore, there are no effective market incentives for developing countries like China to avoid repeating the problems experienced in industrialized countries in the use of coal, for example (burning coal at 30% efficiency in a conventional power plant with few control devices for emissions is less expensive than using coal gasification with combined-cycle turbines and cogeneration to give 70-80% efficiency overall and few emissions). For these and other reasons, Daly and Cobb disagree with the majority of economists, and they are strongly opposed to the expansion of free trade in the global economy and to the use of market forces to solve environmental problems. Although many economists might support imposing a tax on carbon in fossil fuels to address global warming, the real test posed by Daly and Cobb is whether such a policy will actually be implemented on a large enough scale to solve the problem.

## Measuring National Production

Conventional measures of a national production such as Gross National Product (GNP) have been criticized for many years. For example, Baran and Sweezy (1966) argue that certain components such as military expenditures and competitive advertising should be excluded, and Mishan (1972) argues that the expenditures required to offset pollution, such as increased medical expenses, are really costs and not income. More recently, "green" accounting has been advocated to deal with the depletion of forest and fuels and environmental damage (e.g. see Serafy (1989)). The need to improve the measurement of national income is one area in which economists like Solow agree with critics like Daly and Cobb, and Solow states "When it comes to measuring the economy's contributions to the well-being of the country's inhabitants, however, the conventional measures are incomplete. The most obvious omission is the depreciation of fixed capital assets" (Solow, p. 6). It should be noted that the following discussion is limited to considering the use of GNP as a measure of economic production, and it ignores the serious problems of using GNP as a measure of welfare.

The standard alternative to GNP proposed by Serafy and Solow is Net National Product (NNP). The basic idea is to measure the attainable level of consumption keeping the stocks of capital, resources and environmental quality intact. Serafy quotes Adam Smith and John Hicks to show that this concept has a long history in economics, and it is a standard part of cost accounting through the calculation of depreciation for expenditures on physical capital. The recent extensions of this concept cover renewable resources, such as forests, non-renewable resources, such as stocks of fuels, and the costs of environmental damage, such as soil erosion and air pollution. In this expanded form, there is a direct relationship between NNP and the concept of sustainability advocated by environmentalists, and these proposed "measurements .... play a central role in the only logically sound approach to the issue of sustainability that I know" (Solow, p. 7).

The importance of measuring national income differently using NNP is illustrated by Daly and Cobb. They develop an Index of Sustainable Economic Welfare (ISEW) in the U.S.A. for the years 1950-86. From 1950 to 1980, the ISEW increased faster than GNP per capita (2.7% per year and 2.1% per year, respectively). From 1980 to 1986, however, GNP per capita continued to increase at 1.8% per year (in spite of a recession in 1982), but ISEW decreased at a rate of -0.3% per year (Daly and Cobb, p. 419). In other words, the implications for the period 1980 to 1986 about economic growth are completely different when the two measures are compared.

One major problem about NNP is the lack of agreement about which items should be included in NNP and how they should be measured. For example, Daly and Cobb include additions to income, such as the value of household services, as well as deductions, such as the depletion of resources. Alternative methods of measurement are being evaluated by the National Research Council in the U.S.A. in response to concerns raised in a recent study by the U.S. Department of Commerce. Eventually, conventions for measuring NNP may be established by the United Nations and adopted by governments in the same way that the current procedures for national accounts were established.

For this paper, the treatment of stocks of fossil fuels is important. In conventional measures of national income like GNP, direct expenditures on exploration, production, processing (e.g. refining oil or generating electricity) and distribution are included. These measures cover only the cost of labor and the labor embodied in physical capital.

The additional cost in NNP proposed by Serafy is to assume for accounting purposes that compensating investments in other sources of income must be made to offset the depletion of any non-renewable resource.

If an annual revenue of $R_N$ can be obtained from a stock for N more years into the future, the present value of this revenue is $R_N(1 - e^{-rN})/r$, using r as the continuous rate of discounting the future. If the equivalent sustainable revenue is $R_\infty$ per year, it follows that $R_\infty = R_N(1 - e^{-rN})$, and $e^{-rN}$ represents the proportion of the observed revenue from the stock that should be subtracted from GNP. Serafy proposes using the ratio of the stock to the current level of extraction to measure N.

In Table 1, the percentages of revenue required to offset depletion illustrate two points. First, the percentages are negligible if the ratio of reserves to consumption (N) is larger than 100 and the discount rate is 5% per year. Since N = 50 to 100 is a reasonable approximation to the actual situation for oil (Chapman (1993) and 5% is representative of real market discount rates, the implication is that the practical relevance of the offset of revenue is only just emerging (the values of N for other fuels, such as coal, are larger than the value for oil). Second, the offset percentage is much higher if a lower discount rate is used, providing an excellent example of the point raised earlier about the problem of using a market discount rate that is higher than the social discount rate.

There is some disagreement among authors about the correct measure of revenue ($R_N$) to use for fossil fuels. Solow assumes that the offset of revenue is identical to the pure profits above production costs Hotelling's scarcity premium; Solow, p. 11. Serafy assumes that the appropriate offset corresponds to a proportion of revenue net of extraction costs (Serafy, p. 13). In contrast, Daly and Cobb also include the extraction costs in the measure of revenue because extraction costs are "regrettable necessities" (Daly and Cobb, p. 439). In all cases, however, the offsets of revenue would grow exponentially over time at the discount rate (if annual consumption is constant over time and no additions to reserves are discovered). These issues are explored further in Section 5.

The widespread interest among economists and environmentalists in improving the measurement of national income will probably lead to actual changes in, or supplements to, national income accounts. These modifications will reflect the depletion of some resources, particularly fuels and minerals, and possibly changes in environmental quality. One reason for being optimistic is that changes in accounting practices can be implemented by governments and international organizations. For this reason the accounting procedures can also use social rates of discount in the calculations. However, even if general agreement can be reached among countries on how to measure NNP, there is no guarantee that the availability of new information will modify market behavior or improve actual decisions about, for example, how quickly fossil fuels are consumed or whether investments in alternative sources of energy are made.

**Table 1**
**PERCENTAGE OF REVENUE REQUIRED TO OFFSET THE DEPLETION OF A STOCK**

| Years Remaining (N) | Discount Rate (100r) | | |
|---|---|---|---|
| | 1% | 2% | 5% |
| 500 | 1 | 0 | 0 |
| 100 | 37 | 14 | 1 |
| 50 | 61 | 37 | 8 |
| 10 | 90 | 82 | 61 |

## Replacing Non-Renewable Resources

The discussion of measuring national production introduced the argument that the depletion of a non-renewable stocks should be treated as a cost in national income accounts. The implication is that offsetting investments should be made to cover these costs. However, "the setting aside of part of the proceeds for reinvestment is only a metaphor" (Serafy, p. 16). This is the fourth problem of resource economics. There is no guarantee that investments in new technologies to replace non-renewable resources will be made. Once again, the problem is recognized by Solow who states "the cardinal sin is not mining; it is consuming the rents from mining" (Solow, p. 20). The question is how seriously is the problem taken in the formation of current economic policy. The importance of developing "backstop" technologies is obvious to environmentalists (e.g. see Meadows et al. (1992), Chapter 6), but appears to be much less important to economists (Hartwick (1989) is one exception). Economists typically consider the implications of having backstop technologies available rather than the institutional mechanisms and sources of investment needed for their creation.

One possible source of funds for research on new technologies is to tax the use of non-renewable resources through consumption taxes or profit taxes. For example, the rationale for imposing a Petroleum Revenue Tax on oil from the North Sea is discussed by Dasgupta and Heal (p. 371), and they argue that there is "an unavoidable conclusion that there will in general be a strong case for government support for activities designed to promote a technological advance, and this is indeed the typical situation in the most market-oriented economies" (pp. 475-6). Instead of developing a framework to link the revenues from taxation to research expenditures, they focus on the difficulties of predicting technological advances, and cite the case of a Fellow of the Royal Society in England who in 1876 did not recognize the commercial possibilities of electric power (p. 478). One thing does appear to be clear from history. Market forces are generally effective in exploiting new commercial technologies, but they do not necessarily develop these technologies in the first place. Although the future is always uncertain, it will be relatively easy to adapt to new unexpected opportunities, such as inexpensive electric power from fusion, but using fossil fuels with no viable backstop technology may lead to serious problems in the future.

OPEC (Organization for Petroleum Exporting Counties) has had some success over the past 20 years in taxing oil production. The reaction of economists has generally been to discuss the inefficiencies associated with monopolistic behavior and the underutilization of resources. For example, Kay and Mirrlees (1975) state "Economists are well aware that the world's store of exhaustible resources is limited. But in light of the arguments presented here, we wish to suggest that there is a real danger that the world's resources are being used too slowly" (p. 171). An alternative test would be to follow Solow's suggestion and evaluate how the monopoly profits have been spent. To what extent, for example, have these profits been used to establish sustainable levels of income? While there is no simple answer to this question, it is just as pertinent as the question of whether resources are being used too slowly. When issues of global equity are considered in Section 4, economists' concerns about using resources too slowly in industrialized countries are seen to be misplaced.

Summarizing the four problems raised about resource economics, only one appears to have generated some agreement among economists and environmentalists that it can be corrected. This is the problem of incorporating the depletion of resources into national income accounts, and a major reason for this is that the decision to supplement the accounts can be made by governments and international organizations. It is not a market decision. Two of the problems, discounting the future too fast and ignoring environmental externalities, are characteristics of market decisions. Governments must introduce modifications to correct these problems. This does not mean that governments should ignore markets completely in order to solve the problems. Targets for reducing pollution, for example, can be set by governments, but markets can still have an important part to play in determining how to meet the targets efficiently. Economists and their skeptics generally have different levels of optimism about the ability of governments to enforce the needed modifications of markets. For a problem like global warming that requires international cooperation among governments, it is much harder to implement effective policies than it is for regional and national environmental problems. The discussion in the next two sections shows that there is little evidence for optimism about current efforts to deal with global warming.

Both economists and environmentalists have doubts about the fourth problem of replacing fossil fuels and other non-renewable resources. For example, Solow (1986) has criticized the British government for using the taxes on North Sea oil for general revenue instead of investment. Incentives to make investments in new technologies and the associated research activities can be supported by governments. However, markets alone will not provide sufficient incentives for replacing non-renewable resources in a timely way as long as discount rates are high and many external costs of using these resources are ignored. This is the underlying reality for energy policy relating to global warming.

The conclusion is that the optimists among economists believe implicitly that governments will be effective in the future, and that modifications will be implemented to offset the inherent limitations of markets in solving economic and environmental problems correctly. The skeptics on the other hand assume that the increase of competition in international markets will erode the existing capabilities of governments to modify market behavior. Consequently, rather than making gains, environmental standards will be lowered with more competition, and existing gains in improving the safety and health of production workers, for example, will be lost. Furthermore, there is no guarantee that governments will set appropriate policies even if they have the power to do so. David Price (1996) points out that there is no convincing historical evidence that human populations will stabilize economic activities at sustainable levels. For true pessimism about the future, however, one can turn to Kaplan (1994) who predicts that environmental problems and economic inequities will overwhelm many governments, leading to "The Coming Anarchism". Unfortunately, there are already examples of this situation, particularly in Africa. While it is likely that most governments will retain the ability to modify market behavior and implement environmental policies, there is substantial skepticism among environmentalists that this will actually happen. The specific problems of energy are discussed further in the next section.

## 3. CRYING WOLF: IS ENERGY DIFFERENT?

In Aesop's fable, the boy who got bored being on his own while looking after the sheep decided to get some excitement by sounding the alarm that a wolf was attacking the sheep. Eventually, the people in the village, who had responded to a series of false alarms, got tired of being tricked, and when a real wolf appeared, they treated the boy's cries for help as another false alarm and did not go and help him. This story can be viewed as a description of the responses of economists to concerns about running out of resources, and in particular, different sources of energy. Global warming has raised new concerns about the use of fossil fuels, and the question is whether this is another false alarm or a real sign that changes in economic practices should be made.

In 1973, the first major global oil embargo occurred due to the successful efforts of OPEC to control supplies of oil. The resulting increase in the cost of importing oil initiated an alarm about supplies of energy in many countries. This alarm coincided with discussions of the book "Limits to Growth" by Meadows et al. which had predicted that physical limits to continued economic growth would be binding in the relatively near future. The reactions of many economists to this thesis were very hostile (e.g. Kay and Mirrlees). A similar reaction was made by Nordhaus (1992) in a paper titled "Lethal Model 2", which criticizes a revised version of the Meadows' model (1972). The main criticism made by economists was that the model in "Limits to Growth" ignored the potential for technical change and for substituting new types of resources for non-renewable resources. Furthermore, Hotelling had shown over fifty years ago that markets would develop scarcity premiums, and higher prices, automatically for a resource when remaining supplies became limited.

Using experiences with the history of fuels in Britain, economists pointed to a series of false alarms over supplies of energy. When charcoal was used to smelt iron, for example, there was concern about running out of wood and the perceived need to secure new supplies of wood from France (Kay and Mirrlees, p. 150). The solution to this problem was the discovery of how to use coal to smelt iron. Coal became the new source of energy that made the industrial revolution possible. In the mid nineteenth century, the economist Jevons (1865) wrote a book on "The Coal Question" that raised concerns about increasing the costs of industrial production as coal seams became harder to exploit. These concerns about coal supplies in Britain were alleviated by the discovery of oil in the Middle East. Oil became the basis for continued economic growth in the twentieth century.

## Limits on the Rate of Use of Fuels

Looking back at 1973, it appears that the economists who were skeptical about "Limits to Growth" were correct. The high price of oil stimulated exploration for additional sources of oil, and new fields such as Alaska and the North Sea were developed. Improved methods of extraction were also developed that increased the recoverable reserves from existing fields. Efforts on the demand-side were made to increase the efficiency of delivering services from energy. In addition, there was an expansion in the use of alternative sources of energy such as nuclear power. The situation now is that OPEC has been unable to maintain sufficient control over supplies of oil to keep the price as high as it was in the late 1970s and early 1980s. In the U.S.A., the real price of gasoline is about the same as it was before the oil embargo in 1973. All indications are that competitive markets for oil are working effectively at the present time.

Nevertheless, there are some ominous signs about the current situation. Environmental concerns about global warming imply that there should be limits on the rate at which fossil fuels are consumed (e.g. Houghton (1994)). Strategies are now being considered in most industrial countries for stabilizing emissions of greenhouse gases (primarily carbon dioxide from burning fossil fuels) to keep levels at or below the levels emitted in 1990. This goal was initiated by the United Nations Conference on the Environment and Development held in Rio de Janeiro, Brazil in 1992, but it is viewed by many environmentalists as a relatively small step in the right direction. For example, Krause et al. (1992) (Scenario D, p. 197) consider that global emissions of greenhouse gases should be cut to one fifth of the current level to avoid long-term environmental damage. More recently in 1995, a new United Nations conference held in Berlin, Germany concluded with the recommendation that national targets for reductions of greenhouse gases should be set.

The implication of global warming is that concerns are no longer limited to running out of inexpensive sources of fuels. There should also be a limit on the rate of use of fuels. If current levels of emissions already exceed the ability of the biosphere to absorb greenhouse gases without causing long-term harm to the environment, there are important implications for energy policy. First, there is one more external environmental cost of using fossil fuels that is not captured by conventional market forces. Second, and more importantly, equity becomes a central issue. For a given total level of use, one should question the highly skewed situation that currently exists with a small proportion of the world's population having high levels of consumption and most people having low levels. These issues are explored further in Section 4.

## Replacements for Fossil Fuels

Non-economists like Meadows et al. and Hall et al. (1991) treat energy and other natural resources differently from economists. Economists consider energy as just another input, and put their faith in substitution as the solution to scarcity. However, Hall et al. state "elasticities of substitution between natural resources and capital and labor calculated at the level of the firm or industry do not necessarily reflect true substitution possibilities over the economy as a whole. Including the direct and indirect energy costs of producing capital and labor reduces the degree to which capital and labor can be substituted for fuel in production" (Hall et al. p. 893). Their conclusion is that economists typically do not recognize "the realities of physical constraints imposed on our economic possibilities" (Hall et al, p. 896). Even if one questions this view, it seems reasonable to expect that substitution for energy is easier at the high levels of consumption per capita that are observed in industrialized countries than it would be if major increases of energy efficiency were achieved. Observed possibilities for substitution between capital and energy, for example, generally imply reducing the amount of energy wasted. Eventually, energy from fossil fuels must be replaced by another source of energy.

The original plan for replacing fossil fuels in the U.S.A., that was implemented after the oil embargo in 1973, was to use electricity from nuclear power plants. Unfortunately, nuclear power in the U.S.A. appears to be much less viable as an alternative to fossil fuels than it did in the 1970s. The choice posed by Lovins (1977) in between nuclear power and renewable sources of energy is even more pertinent now. With no major new source of energy available at a reasonably low cost, the optimism that many economists expressed after the oil embargo in 1973 must be questioned. Current policy simply assumes that a replacement for fossil fuels, particularly oil, will emerge in time to avoid major disruptions to economic production and life-styles. At the present time, nuclear power is still the most economically viable alternative if the environmental costs of nuclear waste and the political costs of nuclear terrorism are ignored.

Among economists, Daly shares many of the concerns of the critics of conventional economics, and in particular, concerns about the sustainability of continued economic growth. Daly proposes the following three goals for sustainability: 1) to keep the harvest of renewable resources at or below the levels of regeneration, 2) to expand production from renewable sources to match the depletion of non-renewable sources such as fossil fuels, and 3) to keep the amount of pollution at or below the levels that can be absorbed by the environment without adverse effects. The second goal is the most important for this discussion, and it requires some additional explanation. Although it applies to all types of non-renewable resources, the implications for fossil fuels are more serious than for other resources, such as metals, because recycling is not a feasible option. For fossil fuels, improving the efficiency of use is equivalent to replacing them by renewable sources of energy (see Rubin et al. (1992)), and these two alternatives can be treated as synonymous.

Although deforestation and the plight of many international fisheries are current examples of violations of the first of Daly's goals, this goal is still generally accepted as valid by resource economists. Furthermore, the continuing debate over global warming and greenhouse gases is a good example of the growing recognition of Daly's third goal that limits do exist on the capacity of the environment to absorb pollution. Economists may not be the leaders in these debates, but they are involved (e.g. see Nordhaus (1991), and Pearce (1991).

Daly's second goal, however, is the one that is being ignored at the present time. Even though fossil fuels are being consumed at ever higher rates, there is relatively little concerted effort by governments or industry to develop alternative sources of energy. Following the discussion in the previous section, the current costs of conventional sources of energy are too low to bring about major investments in alternative sources.

(In the U.S.A., expenditures on nuclear power are being directed to determining how to clean up existing nuclear sites and how to store nuclear waste rather than on expansion. Expenditures on renewable sources of energy are relatively low, and energy from renewables is still very limited in comparison to the energy from burning fossil fuels.) Although many economists would accept the need for a backstop technology to replace fossil fuels in the future (e.g. Manne and Richels (1990), Hartwick (1989), Cline (1992), and Chapman, the main problems with current energy policy are 1) the imbalance between the limited expansion of renewable sources of energy and the growing consumption of fossil fuels, and 2) the absence of a coherent plan for investing in the development of new technologies for renewable sources of energy.

The contrast between the recommendations of economists and those of environmentalists can be illustrated by comparing the models of Nordhaus (1994) and Meadows et al. The optimum tax on carbon to deal with global warming is found by Nordhaus to be relatively small. Imposing this tax has only minor effects on economic growth, and emissions of greenhouse gases continue to increase. Stabilizing emissions at the level in 1990 (i.e. the proposal adopted at the Earth Summit) is considered to be an expensive and unjustified alternative. (In another study, Rose and Stevens (1993) estimate positive net benefits from a 20 percent reduction in carbon emissions.) In contrast, Meadows et al. conclude that continued economic growth will lead to a collapse of the global economy. Consequently, there is a pressing need to adopt new practices and technologies now because feedback delays in environmental systems make it important to anticipate potential problems in advance.

Given global limits on the rate of use of fossil fuels imposed by the environment, attitudes towards economic equity will affect how fast the transition to renewable sources energy should occur. If the current inequitable situation among countries is accepted, then there is less urgency to develop new technologies for energy. On the other hand, if it is recognized that the use of energy should increase in developing countries to allow for growth of energy use in Low Income and Middle Income countries is becoming increasingly important, and policies to deal with global warming must reflect this reality.

The projections for 2025 in Tables 2 and 3 are based on the assumptions summarized in Table 4. Projections of growth rates for population correspond to current United Nations forecasts and imply lower rates of growth in the future (Population Reference Bureau (1991)). Projected growth rates in GNP per capita are held constant at the annual rates observed from 1965 to 1990. The High projected growth rates for energy correspond to the same annual rates as the period 1965 to 1990, and the Medium and Low rates are one percent and two percent less than the High rates, respectively. Using the Low Energy rates, energy use declines slightly in High Income countries. In all three cases, however, global energy use increases from 1990 to 2025. Table 2 shows the levels in 2025, and Table 3 shows the changes in levels from 1990 to 2025.

Even though the rate of population growth decreases, the increase of population from 1990 to 2025 in Table 3 is still larger than the increase from 1965 to 1990, and only 3 percent of this increase occurs in High Income countries. The increase in global GNP from 1990 to 2025 is over three times bigger than the increase from 1965 to 1990. This is also the case for energy use for the High Energy rates of growth. Even with the Low Energy rates of growth, the increase in total energy use from 1990 to 2025 is the same as the increase from 1965 to 1990, and all of the increase is in Low and Middle Income countries in this case. The implication is that the prospects for stabilizing emissions of greenhouse gases are daunting even if the level of population eventually stabilizes at 11 billion. The important question is how closely are economic growth and energy use linked together. Most economists would agree with Nordhaus that the cost of reducing emissions of greenhouse gases from fossil fuels would be substantially lower rates of economic growth.

## Table 2
## POPULATION, ECONOMIC OUTPUT & ENERGY CONSUMPTION

| | | Level[b] | Percentage Share[a] | | |
|---|---|---|---|---|---|
| | | All Countries | Low Income Countries | Middle Income Countries | High Income Countries |
| **1965** | | | | | |
| 1. Population | | 3 billion | 58 | 20 | 22 |
| 2. GNP | | 8 trillion | 4 | 10 | 86 |
| 3. Energy | | 3 billion | 7 | 15 | 78 |
| **1990** | | | | | |
| 1. Population | | 5 billion | 62 | 22 | 16 |
| 2. GNP | | 19 trillion | 6 | 12 | 82 |
| 3. Energy | | 7 billion | 15 | 22 | 63 |
| **2025**[c] | | | | | |
| 1. Population | | 8 billion | 65 | 24 | 11 |
| 2. GNP | | 55 trillion | 9 | 16 | 75 |
| 3. Energy | (high) | 21 billion | 34 | 29 | 37 |
| | (medium) | 15 billion | 34 | 29 | 37 |
| | (low) | 11 billion | 34 | 29 | 37 |

a Country groups are defined in the Source.

b The units are 1990 $US for GNP (Gross National Product), and metric tons of oil equivalent for Energy.

c Derived from the assumptions summarized in Table 4.

Source: Values for 1965 and 1990 are derived from Tables 1 and 5 of the "World Development Report 1992", World Bank.

## Table 3
## CHANGES OF POPULATION, ECONOMIC OUTPUT AND ENERGY CONSUMPTION[a]

| | | Change of Levels[b] | Percentage Share | | |
|---|---|---|---|---|---|
| | | All Countries | Low Income Countries | Middle Income Countries | High Income Countries |
| **1965-1990** | | | | | |
| 1. Population | | 2 billion | 68 | 24 | 8 |
| 2. GNP | | 11 trillion | 7 | 14 | 79 |
| 3. Energy | | 4 billion | 22 | 28 | 50 |
| **1990-2025** | | | | | |
| 1. Population | | 3 billion | 70 | 27 | 3 |
| 2. GNP | | 36 trillion | 11 | 18 | 71 |
| 3. Energy | (high) | 14 billion | 41 | 33 | 26 |
| | (medium) | 8 billion | 48 | 35 | 17 |
| | (low) | 4 billion | 64 | 42 | -6 |

[a] Derived from Table 2

[b] Same units as Table 2

## Table 4
## AVERAGE ANNUAL GROWTH RATES
## (PERCENT)

| | | Low Income Countries | Middle Income Countries | High Income Countries |
|---|---|---|---|---|
| **1965-1990** | | | | |
| 1. Population[a] | | 2.2 | 2.2 | 0.8 |
| 2. GNP/capita[a] | | 2.9 | 2.2 | 2.4 |
| 3. Energy/capita[a] | | 4.1 | 2.6 | 1.5 |
| **1990-2025** | | | | |
| 1. Population[b] | | 1.5 | 1.6 | 0.3 |
| 2. GNP/capita[b] | | 2.9 | 2.2 | 2.4 |
| 3. Energy/capita | (high)[b] | 4.1 | 2.6 | 1.5 |
| | (medium)[b] | 3.1 | 1.6 | 0.5 |
| | (low)[b] | 2.1 | 0.6 | -0.5 |

[a] Derived from Tables 1 and 5 of the "World Development Report 1992", World Bank.

[b] Specified Values.

The results presented in Tables 2-4 about the future are simple accounting calculations to illustrate the factors that are contributing to global warming. These results are, however, generally consistent with the current forecasts of energy consumption and the corresponding emissions of carbon made by the Energy Information Administration (EIA) (1997) for different countries for 2000 and 2015. The EIA forecasts of carbon emissions summarized in Table 6 are derived using three sets of economic forecasts summarized in Table 5. Countries are grouped into Industrialized, Eastern Europe and the Former Soviet Union (EE/FSU) and Developing. The High Income group in Tables 2-4 corresponds roughly to Industrialized plus EE/FSU, and the Middle and Low Income groups correspond to Developing.

Comparing the assumptions about future economic growth in Table 2 and the Reference case in Table 5 shows that the global growth rates are both close to 3.1 percent per year (note that the time periods are 1990 to 2025 in Table 2 and 1995 to 2015 in Table 5). The growth rates for the EIA Reference forecasts in Table 5 are lower for Industrialized countries (2.5 percent) compared to High Income countries (2.7 percent implied in Table 2), but combining Industrialized and EE/FSU would increase the EIA growth rate. The EIA growth rates for Developing countries are slightly higher (4.7 percent) compared to Low Income countries (4.3 percent implied in Table 2). The range of EIA growth rates from Low to High Economic is relatively small for Industrialized countries (1 percent) compared to most Developing countries (3 percent), China (4.5 percent) and EE/FSU (4.5 percent).

An important implication of the EIA forecasts of carbon emissions in Table 6 is that the underlying growth of energy use will be lower than economic growth in all countries (2.2 percent per year for aggregate energy compared to 3.1 percent for global GNP in Table 5). It should be noted that this implies a major change from the historical experience for Low Income countries in Table 4 (4.1 percent for energy per capita compared to 2.9 percent for GNP per capita over the period 1965 to 1990). The reason

## Table 5
## ANNUAL GROWTH RATES OF REAL GROSS NATIONAL PRODUCT

| REGION | 1970-80 | 1980-90 | 1995-2015 | | |
|---|---|---|---|---|---|
| | | | Low | Reference | High |
| United States | 3.0 | 2.6 | 1.9 | 2.4 | 2.9 |
| Other N. America | 3.0 | 2.6 | 1.9 | 2.4 | 2.9 |
| Western Europe | 3.0 | 2.6 | 2.0 | 2.5 | 3.0 |
| Industrialized Asia | 4.3 | 4.0 | 2.3 | 2.8 | 3.3 |
| **INDUSTRIALIZED** | **3.2** | **2.8** | **2.0** | **2.5** | **3.0** |
| **EE/FSU** | **3.2** | **2.1** | **2.1** | **3.6** | **6.6** |
| China | 5.8 | 8.9 | 4.3 | 7.3 | 8.8 |
| India | 6.4 | 6.3 | 3.8 | 5.3 | 6.8 |
| Other Asia | 6.4 | 6.3 | 3.8 | 5.3 | 6.8 |
| Middle East | 4.8 | 1.5 | 1.2 | 2.7 | 4.2 |
| Africa | 4.2 | 1.4 | 1.9 | 3.4 | 4.9 |
| Central & S. America | 5.8 | 1.1 | 2.0 | 3.5 | 5.0 |
| **DEVELOPING** | **5.4** | **3.3** | **na** | **4.7** | **na** |
| **TOTAL** | **3.5** | **2.8** | **na** | **3.1** | **na** |

EE/FSU Eastern Europe/Former Soviet Union

Source: US Energy Information Administration, International Energy Outlook 1997.

# Table 6
# GLOBAL EMISSIONS OF CARBON
## (Million metric tons)

| REGION | 1990 | 1995 | 2000 | | | 2015 | | |
|---|---|---|---|---|---|---|---|---|
| | | | Low | Reference | High | Low | Reference | High |
| United States | 1337 | 1424 | 1515 | 1543 | 1575 | 1688 | 1798 | 1939 |
| Other N. America | 224 | 240 | 278 | 283 | 289 | 351 | 372 | 396 |
| Western Europe | 1016 | 1014 | 1059 | 1081 | 1098 | 1209 | 1279 | 1346 |
| Industrialized Asia | 408 | 473 | 499 | 514 | 523 | 584 | 625 | 661 |
| **INDUSTRIALIZED** | **2985** | **3151** | **3352** | **3421** | **3485** | **3831** | **4074** | **4341** |
| **EE/FSU** | **1339** | **893** | **967** | **1012** | **1087** | **1087** | **1251** | **1625** |
| China | 625 | 821 | 930 | 1031 | 1076 | 1294 | 1838 | 2167 |
| India | 159 | 221 | 252 | 276 | 296 | 384 | 490 | 612 |
| Other Asia | 307 | 432 | 511 | 557 | 597 | 716 | 904 | 1122 |
| Middle East | 203 | 254 | 244 | 265 | 282 | 276 | 344 | 418 |
| Africa | 205 | 248 | 251 | 267 | 281 | 290 | 352 | 422 |
| Central & S. America | 189 | 220 | 243 | 263 | 282 | 343 | 452 | 585 |
| **DEVELOPING** | **1687** | **2197** | **2431** | **2660** | **2815** | **3303** | **4379** | **5325** |
| **TOTAL** | **6012** | **6241** | **6750** | **7093** | **7387** | **8222** | **9704** | **11292** |

**EE/FSU Eastern Europe/Former Soviet Union**

**Source: US Energy Information Administration, International Energy Outlook 1996.**

given by EIA (p. 16) is "energy efficient technologies used in industrialized nations will increasingly be adopted in the developing nations". To this extent, the EIA forecasts of energy use are optimistic, and greater dependence on electricity as a source of energy in Developing countries, for example, could result in higher growth rates for energy use.

The growth rates in future carbon emissions corresponding to the forecasted levels in Table 6 are very similar to the corresponding growth rates for energy, and the growth rates for total emissions and total energy are identical (2.2 percent per year for 1995 to 2015). This is the same growth rate for energy as the Medium Energy scenario in Table 2, and consequently, the simple accounting procedures used in Tables 2-4 for the Medium Energy scenario are in general agreement with the EIA Reference case. The main difference is that it is assumed in Tables 2-4 that ratio of growth of energy and GNP are lower (higher) in High (Low) Income countries than the EIA forecast, implying that greater restraint over energy use is exhibited in the High Income countries. An alternative way to match this restraint would be to subsidize the transfer of energy-efficient technology to Low Income countries, and this is a valid way to interpret the assumptions made by the EIA about technology transfer. Either way, substantial economic sacrifices will be required in High Income countries beyond business-as-usual assumptions. The willingness of the public in High Income countries to make such sacrifices for people in Low Income countries is discussed later in this section.

The most important implication from the forecasts of carbon emissions in Table 6 is that all of the Low Economic forecasts for 2000 and 2015, with one exception, are substantially higher than the levels in 1990. The exception is EE/FSU due to the recent collapse of these economies. There is no indication that emissions of carbon from fossil fuels, the major source of greenhouse gases, will stabilize at 1990 levels in any of the Industrialized regions even with pessimistic assumptions about economic growth. Under the Low Economic scenario, emissions from Industrialized countries in 2015 increase by almost 30 percent from 1990, and in Developing countries, the equivalent increase is almost 100 percent. These forecasts are much higher than the levels required to meet the commitments agreed to at the Earth Summit in 1992. In the Reference and High Economic scenarios, forecasted emissions from Developing countries are higher than emissions from Industrialized countries in 2015, reinforcing the point made earlier about the importance of the growth of energy use in Low Income countries (Table 3).

Another important implication from Table 6 is the current position of the U.S.A. which contributed over one fifth of total emissions of carbon in 1990 and 1995. On a per capita basis, emissions of carbon and energy use are much higher in North America than they are in Western Europe or Japan, for example. This is the primary reason why any global policies to stabilize carbon emissions will require leadership and action from the U.S.A. If there is a reluctance to reduce emissions in the U.S.A., it is highly unlikely that other countries will do so. There are responsibilities associated with being a super energy consumer as well as being a super power.

## Attitudes Towards Economic Equity

Many non-economists are probably quite skeptical about the central argument of market economists that the world will be a better place leaving economic decisions to the self-interests of individuals and firms. Few would doubt that self-interest is a powerful motivating force, but it is not immediately obvious why indulging one's own desires is going to help other people. Nevertheless, profits for firms and consumption for individuals are treated as the dominant factors influencing decisions in market transactions. Sen (1977) discusses this problem in his paper "Rational Fools", and he states that "the exclusion of any consideration other than self-interest seems to impose a wholly arbitrary limitation on the notion of rationality."

There are economic problems which must be solved in practice and are related directly to equity. For example, Sen (1992) discusses the plight of people who are incapacitated and are unable to earn a living. He discusses their "entitlements" to receive support, and shows the limitations of conventional utilitarian models which focus on consumption rather than the capabilities that can be attained. In welfare economics, the problem of equity is implicitly left to governments through the scheme used to weight the utilities of individuals. This provides the rationale for progressive taxation of incomes and the existence of welfare programs (e.g. see Atkinson (1983)). However, established procedures used by governments to redistribute income from the rich to the poor are being challenged in many countries. In particular, there has been a substantial redistribution of income after taxes in favor of the rich (see Phillips (1990) and Bronfenbrenner et al. (1996). Frank and Cook (1995) characterizes these changes as a central feature in a "winner-take-all" society.

Frank (1988) also addresses a different question. He notes that some people are altruistic and others simply follow their own interests. The latter group represents the typical individuals modeled by economists. Frank asks the question of how can altruists survive in a competitive economy. He argues that certain problems, such as the prisoner's dilemma, can be solved better by altruists who are willing to cooperate with others (Frank calls this the Commitment Model). Reassuringly, people with self-interested motives find it difficult to cheat when solving these problems by pretending to be trustworthy. In experiments, people tend to behave in a fair way more frequently than the predictions from the self-interest model would imply. These findings are also supported by Andreoni and Miller (1993), and such behavior influences "warm glow giving" to charities and payments for public goods such as Public Radio. It is interesting to note that taking graduate courses in economics appears to reduce the likelihood of behaving cooperatively and to increase self-interest (Frank, pp. 226-9).

To summarize the current situation in the U.S.A. relative to other countries, ranges of wages have been reported by Gottschalk and Smeeding (1996) using data from 1991 from the Luxembourg Income Study. Comparing real income per household (based on purchasing power parity and corrected for household size) shows that the income level for the tenth decile in the U.S.A. is lower than the equivalent levels in 13 other industrialized countries, primarily in Europe. On the other hand, the median income in the U.S.A. is the highest among the 14 countries, and the income for the ninetieth percentile is substantially higher than it is in the other countries. In other words, the range of incomes from the tenth to the ninetieth decile in the U.S.A. is the largest by a long way. In fact, current economic conditions in the U.S.A. do not stand up very well to Samuel Johnson's standard that "a decent provision for the poor is the true test of civilization" (quoted by Atkinson, p. 224).

In a recent study "The State of Americans" by Bronfenbrenner et al., a number of "disturbing facts and figures" about the population are discussed that present a different perspective on the aggregate picture of real economic growth over the past two decades. The issues considered include crime, education, health and income. To focus on the single characteristic of household income in the U.S.A., McClelland (1996) (Figure 3-5) compares the changing distributions of incomes for different time periods. From 1947 to 1973, real incomes in all quintiles increased at over two percent per year, and the rate of growth in the lowest quintile (2.9%) was the biggest and the rate in the highest quintile (2.42%) was the smallest. Increasing affluence led to greater equity, following a traditional Kuznets curve for a high income country. The situation from 1973 to 1992 was exactly the opposite. Real incomes in the lowest two quintiles actually decreased, and the highest annual rate of growth (0.93%) occurred in the highest quintile. Overall, there was a small decline in the real median income, and the inequality of the distribution of income increased substantially.

To some extent, the decline in real incomes for poor families over the past 25 years in the U.S.A. can be associated with a loss of manufacturing jobs for unskilled workers due to increasing competition in international markets. The result is that a significant number of families in the U.S.A. are under economic stress and feel threatened by competition for jobs with low income countries like China and Mexico. This segment of the public is unlikely to be sympathetic to increasing taxes on fuels or subsidizing the transfer of energy-efficient technology to competing countries. These, however, are exactly the policies that are needed to address global warming.

### Attitudes Towards the Environment

Demonstrating that public attitudes towards economic inequality can change in a competitive world is an important step. It raises a similar question of how public attitudes affect the solutions chosen for environmental problems like global warming. Identifying the origin of attitudes about the environment in a society is difficult, but education, religion and political leadership can and do modify the attitudes of individuals. Roderick Nash (1989) describes how attitudes towards nature have evolved from survival and self-interest to "ecological egalitarianism" with legal rights for nature as well as for people. In spite of the current success of market capitalism relative to planned economies, many people see the need for changes in public attitudes. For example, Aleksandr Solzhenitsyn (1993) argues for more self-restraint by individuals to protect the environment, and he states "The time is urgently upon us to limit our wants. It is difficult to bring ourselves to sacrifice and self-denial because in political, public and private life we have long since dropped the golden key of self-restraint to the ocean floor." Bill McKibben (1995) has argued that people in the U.S.A. must learn to live "lightly on the earth," and the current Vice-President, Al Gore (1992), has described a moral basis for his approach to solving environmental problems. However, these efforts to change public attitudes have yet to achieve tangible effects on current energy policy relating to global warming.

The need for a broader vision for economic analysis is recognized by some economists. For example, Heilbronner (1992), in reviewing a biography of John Maynard Keynes by Robert Skidelsky, quotes "Keynes addressed the world as a priest, not as a technician. And though he rearranged its theology, economics spoke, through him, as a church, not as a branch of differential calculus." Heilbronner concludes 'I suspect that we will not discover the way out of the present impasse until we find an economics that projects a moral vision along with a technical diagnosis comparable to that of the General Theory [of Employment, Interest and Money] ...' (p. 9). A corollary to this statement is the question of whether economists should remain passive and treat current public attitudes as given and fixed, because it is unlikely that satisfactory solutions to global warming will be implemented unless changes in public attitudes occur.

Stabilizing global emissions of greenhouse gases will require reductions of emissions in industrialized countries, lower rates of growth of emissions in developing countries and the development of new sources of energy and energy-efficient technologies for use in all countries. There is little hope that these policies will be adopted unless there is widespread support in high income countries for reducing income inequities among countries, and public attitudes throughout the world accept the need to stabilize emissions of greenhouse gases. It was argued above that the U.S.A. must take leadership in addressing global warming because the levels of energy use and emissions of greenhouse gases in the U.S.A. are so large in total and on a per capita basis. It is also true that unilateral action by the U.S.A. will not be sufficient to solve the problem unless it leads to equivalent actions in other countries. The predicament is that public attitudes in the U.S.A. are not compatible with taking leadership at this time. Attitudes towards energy are reflected by the low taxes paid on gasoline relative to most other countries. The vulnerability of imported supplies of oil has always been an influential factor in most industrialized countries, but the tradition in the U.S.A. is based on abundant domestic supplies. At the present time, the evidence in the U.S.A. about the use of fossil fuels supports the pessimism of environmentalists about the inability of competitive markets to deal with global warming.

# 5. A MARSHALLIAN PERSPECTIVE ON FOSSIL FUELS

Many environmentalists find it hard to understand the economic logic that makes the price of a gallon of gasoline lower than the price of a gallon of beer. Beer is a renewable product that is easy to make at home and has been in production from the time of the ancient Egyptians. Petroleum, on the other hand, is a complex chemical product that is expensive to synthesize, is a valuable feedstock for producing plastics and a compact source of energy for transportation. Beer is relatively inexpensive to produce, but there are other costs and beer is generally subject to special taxes on alcohol (the tradition in British income accounts is to treat alcohol as a "vice"). The price of gasoline includes the costs of extraction, refining and distribution as well as some taxes. In European countries and Japan, the taxes on gasoline are high (over 70 percent of the total price in Europe, for example). In the U.S.A., only 27 percent of the average price of gasoline is for taxes, and most of this revenue is directed to highway improvements (based on data for 1992, EIA (1994)). The actual costs of production are less than a dollar per gallon in all of the European countries, Canada and the U.S.A. The low cost of producing oil reflects many improved techniques for the extraction and refining of oil that have been introduced by the oil industry. In the U.S.A., for example, substantial increases in oil reserves have been made since the discovery of oil in Alaska, but these increases came from improved methods of recovery and not from finding new oil fields. Globally, current projections are that the real price of crude oil will not increase over the next 20 years, in spite of continued growth of consumption at a projected rate of increase of 2.1 percent per year in the Reference case (EIA 1997). Given the prospect of increasing growth of oil consumption with low prices, most economists would argue that this is an example of competitive markets working well. For example, the efforts by

OPEC to capture monopoly profits in the mid seventies were undermined by the mid eighties through increases in production capacity in other regions of the world.

### Hotelling's Scarcity Premium

The theoretical explanation of how owners of a non-renewable resource like oil behave under competition was developed by Hotelling over sixty years ago. The basic structure is that the present value of true profits (the scarcity premium) above the total cost of production, including a fair return on investment, must be the same for every point of time in the future. If this was not the case and an owner believed that discounted profits would be higher at some time in the future, it would be economically rational to cut current production and wait until profits increased. Since these decisions would be based on market rates of interest, which are generally higher than social rates of discount (see Section 2 above), there is still a tendency to produce too much in the current period. To varying degrees, this overproduction is offset by governments through consumption taxes on fuels such as gasoline. These taxes could also reflect internalizing environmental externalities such as urban smog.

The implication of Hotelling's rule is that the true profit or scarcity premium measuring the future exhaustibility of a non-renewable resource will grow at the market rate of interest. This is exactly the same feature exhibited by the adjustment factors in national income accounts for the depletion of a stock (Table 1). Consequently, the scarcity premium has similar characteristics to the adjustment factor, and it is trivially small if interest rates are high and the time horizon to exhaustion is long. For actual levels of reserves, Kay and Mirrlees have shown that the scarcity premium would be essentially zero, and the economically efficient price of crude oil, for example, should be very close to the long-run marginal cost of extraction. (In another study, Flaim and Mount (1978) have argued that actual oil prices have traditionally been based on average cost pricing rather than marginal cost pricing, and as a result, market prices are lower than the efficient prices.)

With this background, how would economists address the problem of global warming? The two main arguments for modifying market behavior would come from the discussion in Section 2. First, one could argue that there are environmental externalities, associated with future damage from global warming, that are not reflected in the prices paid for fuels. A tax on carbon emissions should be imposed to internalize the externality. Second, one could argue that high market discount rates make investment in research on renewable sources of energy commercially unattractive. Some government expenditure on this research should be made to develop economically viable alternatives for fossil fuels.

The standard economic arguments for taking action to address global warming depend on balancing the costs of reducing emissions of greenhouse gases with the future benefits of moderating the changes of climate. Measuring these costs and benefits is extremely difficult to do. Many conflicting recommendations would be developed by different special interests, illustrated by the contrast between the minor adjustments proposed by Nordhaus and the more drastic changes proposed by Meadows et al. (see Section 3). Given the difficulties in reaching agreement over these economic magnitudes, it seems probable that greater dependence would be placed on the natural sciences by recommending a physical limit on annual emissions of greenhouse gases. This is the strategy that is emerging from the series of United Nations conferences on climate change following the Earth Summit in 1992. Given a target level of emissions, economists could develop economically efficient ways to meet the target by, for example, establishing markets for carbon emissions. To be effective, all policies would require cooperation among governments over monitoring and enforcement on a global scale, and this could not be accomplished without widespread support from the public throughout the world.

## Taking Stores from Nature's Storehouse

A constructive step towards winning public support for policies to address global warming would be to develop an economic evaluation of fossil fuels that is more compatible with the concerns of environmentalists (see Section 3). More specifically, it would be desirable to understand why environmentalists place more value on fuels than the economic rules of efficiency established by Hotelling. Many environmentalists would support Daly and Cob in wanting to see more than the "ad hoc adjustments" that measure external costs, for example. The basis for developing a reconciliation between economists and environmentalists is to use the concept of "nature's storehouse" proposed by Alfred Marshall, and I am indebted to Mohammed Dore for encouraging me to read Marshall's "Principles of Economics".

Modern neoclassical economics follows the tradition of Walrasian general equilibrium theory. The decision to follow this path can be traced back to the beginning of this century. "Alfred Marshall, the founder of neoclassical economics, was highly sensitive to the historical character of the actual economy. Nevertheless, economists on the whole wanted economics to become increasingly scientific, and their idea of science was based on physics rather than evolutionary biology .... ... Milton Friedman notes of economists that we 'curtsy to Marshall, but we walk with Walras' " (Daly and Cobb, p. 20). The theory proposed by Hotelling for determining the scarcity premium on the extraction of fossil fuels is an extension of the static Walrasian general equilibrium model to include forward markets. Hence, it is appropriate to consider what differences would exist if a Marshallian approach had been followed.

Marshall made a clear distinction between the economic return to land and the economic return to a mine. "This difference is illustrated by the fact that the rent of a mine is calculated on a different principle from that of a farm. The farmer contracts to give back the land as rich as he found it: a mining company can not do this; and while the farmer's rent is reckoned by the year, mining rents consist chiefly of "royalties" which are levied in proportion to the stores that are taken from nature's storehouse" (Marhsall p. 167).

Marshall goes to considerable lengths to understand how the determinants of market prices differ in the short-run and the long-run, and the corresponding dynamic effects of imposing taxes. As part of the discussion in Chapter IX, Marshall considers the implications of placing taxes on a windfall if a "meteoric shower of a few thousand large stones harder than diamonds fall in one place" (Marshall p.415). These stones are ideal for use in machine tools. Three different situations are considered. The first assumes that there are no production costs to the owner of the stones if they are sold to manufacturers. The second assumes that some effort must be expended by the owner to find the stones, but the total supply is still fixed, and the third assumes that an unlimited number of stones can be produced at some uniform cost. In the first case, the price is determined by the demand for the services of the stones or by the cost of producing alternative cutting tools, and "the value of a stone could not much exceed the cost of producing tools" (i.e. the backstop technology) (Marshall p. 416). At the other extreme, the third case is an example of a conventional supply situation with an infinite supply elasticity. Consequently, the price is determined by the cost of production. The second case is an intermediate situation, which is a reasonable approximation to the characteristics of mining, and the price is determined by the intersection of the demand for the services and the supply of the effort to find the stones.

Placing a tax on the stones in the first case, which would have to be bounded at less than the cost of the backstop technology, would reduce the rental income of the owner of the stones. In the third case, a tax would increase costs for all production processes using the stones. The tax would be paid indirectly by anyone purchasing the products and not by the original owners (producers) of the stones. For the second case, the tax affects both the owners of the stones and the production costs of the users of the stones. The relative effects of the tax on the owners and the users change over time and are determined by the rates of adjustment.

Marshall raises three concepts that are relevant to understanding the use of fossil fuels. First, fossil fuels are examples of nature's "stored up treasures". Second, the cost of a backstop technology places a limit on the level of taxes that can be imposed, and third, dynamic adjustment processes matter when evaluating the effects of different policies. The implications of these concepts can be illustrated by considering the cost of extracting oil, $C$, the market price for crude oil, $P_m \geq C$, and the price of a replacement source of renewable energy (the backstop technology), $P_b \geq P_m$. The Marshallian value of nature's treasure is $(P_b - C)$, and this difference also measures the maximum tax that could be imposed (this was the issue that was identified by Mohammed Dore). In contrast, the primary concern of most economists is to compare the "profits" from extraction, $(P_m - C)$, to Hotelling's scarcity premium.

The important difference between the conventional Hotelling approach and the Marshallian approach is in the measure of value used. Using Hotelling's rule, the market price $P_m$ and profits $(P_m - C)$ are the focus of attention. Concern is expressed if profits are too high due, for example, to monopoly behavior. This leads to statements about using resources too slowly because prices are too high. When market rates of discounting are used, Hotelling's scarcity premiums are very small until stocks of the resource are nearly exhausted, and they then increase rapidly in magnitude. In Section 2 of this paper, Solow and Serafy use profits $(P_m - C)$ as the measure of income from the resource. Daly and Cobb use market price $(P_m)$ as their measure. For a Marshallian, however, the correct measure is the rent $(P_b - C)$.

Consider a simple example for oil. Chapman uses an ethanol fuel to represent the backstop technology in his analysis of depleting reserves of oil. He shows that the transition to this renewable source of energy occurs about 60 years from now using $50 per barrel as the price of the backstop technology. Assuming that the average cost of production is currently $10 per barrel and the market price is $15 per barrel, the standard measure of profit (e.g. due to the monopoly behavior of OPEC) is $5 per barrel. For a Marshallian, however, the rent is $40 per barrel.

In reality, the cost of a backstop technology in the future is uncertain, and furthermore, the cost can be reduced through expenditures on research. Consequently, a Marshallian should judge current practices governing the depletion of oil in terms of how effectively the $40 profit is being used. Currently, most of the profit is being dispersed to people using oil in the form of low prices for oil. In the example, only $5 of the $40 rent is being collected by monopoly power or through taxes on fuels. The justification for these taxes is generally to account for external environmental costs (e.g. urban smog) or to pay for complementary products (e.g. roads). In other words, they are examples of the conventional corrections to markets discussed in Section 2.

To a Marshallian, the availability of inexpensive sources of non-renewable energy is treated as a temporary phenomenon. It is unwise under these circumstances to develop social systems that are heavily dependent on the continued availability of inexpensive energy. One reason is that the rate of adjustment to higher prices would be relatively slow (e.g. changing the dispersed life style of suburbia in the U.S.A.). It would be better to look at stocks of fossil fuels as a gift from nature that can be used to develop better social systems in the future. The only way to reconcile this Marshallian view with standard economic theory, and current energy policy, is to assume that an inexpensive backstop technology will be developed to replace fossil fuels.

If one accepts the view that nuclear power (both fusion and fission) is not a viable alternative to fossil fuels, then the importance of renewable sources of energy is clear. Since renewable sources of energy are relatively expensive, the Marshallian and environmentalists' critique of current energy policy stands. Furthermore, the total amount of energy obtained from renewable sources is likely to be relatively small compared to typical projections of global energy needs made by economists. A major reason for this is that many renewable sources, such as biomass, compete for land with agriculture. With growing populations throughout the world, the demand for agricultural land will increase to expand the production of food. Brazil provides an example of the problems of high food prices associated with allocating prime agricultural land to the production of sugar for ethanol. Keeping this land out of food production provided a major incentive for the deforestation of the Amazon to support the expanding population in northern Brazil.

The overall conclusion is that current energy policy is incompatible with a Marshallian perspective. The gift of fossil fuels should be used by society to develop new technologies that improve energy efficiency and lower the costs of energy from renewable sources. Daly's concept of sustainability for energy is more than an accounting scheme. At the present time, only a small proportion of the Marshallian profit is being used to develop appropriate technologies to replace fossil fuels. The biggest share of the profit is going to support the current consumers of oil and to encourage high levels of consumption. By focusing on the importance of the cost of alternative sources of energy, the Marshallian approach provides a rationale for greater restraint in the cost of alternative sources of energy, the Marshallian approach provides a rationale for greater restraint in the use of fossil fuels, and it is more consistent with the views of environmentalists that the value placed on fossil fuels in competitive markets is much too low.

## 6. CONCLUSIONS

The primary objective of this paper is to explain why many environmentalists are critical of current economic theory about fossil fuels, and to provide an alternative economic framework for analyzing energy issues. The transition from using non-renewable to renewable sources of energy and the environmental problem of global warming are used to illustrate these issues. The five main conclusions are 1) that markets discount the future, and the importance of developing alternatives for fossil fuels, too much, 2) that the contribution of energy to the economy is under-valued by economists, 3) that the environmental costs of energy use are also under-valued, 4) that most growth in the use of fuels will be in countries with low incomes per capita, and 5) that limiting the rate of use of fossil fuels for environmental reasons has implications for economic equity.

Problems with market solutions to resource problems have been recognized by economists. These include 1) discounting the future too fast, 2) ignoring environmental costs, 3) ignoring the depletion of stocks of resources in measuring national production, and 4) the low level of investment in developing alternatives for non-renewable resources. Economists who are optimistic about the future for energy must believe that governments can and will correct these deficiencies in markets (or that the deficiencies are of minor importance). Pessimists about the future, on the other hand, consider that increasing competition in the global economy will undermine the role of governments, and may erode gains that have already been made in addressing environmental problems.

Criticisms by economists of the gloomy predictions made by environmentalists about energy implicitly assume that inexpensive substitutes for fossil fuels will be found, but there are two important changes that have occurred over the past twenty years in scientific knowledge about the use of fossil fuels. First, concerns about global warming have put a limit on the global rate at which fossil fuels should be used. Second, current prospects for the nuclear industry are poor, and it appears unwise to assume that large amounts of inexpensive energy will come from this source in the future. Consequently, the lack of economically viable sources of renewable energy should be of great concern. In addition, placing limits on the rate of use of fossil fuels puts economic equity among countries as a central issue for energy policy. It is interesting to note that this is consistent with the conclusions reached by Eric Hobsbaum (1996) in his economic history of the twentieth century. He recognizes that demographics and ecological problems will be decisive in the long run, and concludes "If these decades proved anything it was that the major political problem of the world . . . . was not how to multiply the wealth of nations, but how to distribute it for the benefit of their inhabitants."

Turning to the specific issue of energy policy and the problem of global warming, it was argued in Section 3 that the high levels of energy use in the U.S.A. make it essential for the U.S.A. to take leadership in implementing solutions. This can be done by showing more restraint in the use of fossil fuels and developing new technologies for increasing energy efficiency and for renewable sources of energy. Many existing technologies for improving energy efficiency are already cost effective (see Rubin et al.), but they have not been adopted due to various market distortions (e.g. different incentives for renters compared to owners of buildings). Nevertheless, an underlying problem is the public's belief that energy should continue to be inexpensive. Even though the U.S.A. has shown leadership in reducing many sources of air pollution (e.g. acid rain, urban smog and cigarettes), little restraint has been shown in the use of fossil fuels, particularly for automobiles and road transportation. In this respect, the U.S.A. lags behind other countries in leading the way to finding solutions for global warming.

Although leadership from the U.S.A. is required, most of the growth in the global use of energy will occur in low income countries. Increased energy efficiency and a greater reliance on renewable sources of energy will also be needed in these countries. In fact, it may be easier to build the foundations for efficient energy systems in low income countries now than it would be to change established and inefficient systems sometime in the future. To the extent that knowledge about improved energy technologies exists in high income countries, it will be necessary to find ways to encourage (e.g. through subsidies) their adoption in low income countries. On the fiftieth anniversary of the Marshall plan, it is appropriate to remember how this act of generosity by the U.S.A. helped to rebuild Western Europe after the Second World War. A similar plan to deal with global warming is needed at this time. Unfortunately, the increased inequities of income that have developed in the U.S.A., and the economic pressures faced by many people from global competition, make it unlikely that the public will be willing to support steps to stabilize emissions of greenhouse gases before other countries take action.

Existing policies for reducing emissions of greenhouse gases in the U.S.A. are ineffective. The lack of interest in "no regrets" options for improving energy efficiency and the dependence on "voluntary restraints" in the President's Climate Change Action Plan are examples. The results of the policies are illustrated by the forecasts of substantial increases of carbon emissions in the U.S.A. shown in Table 6. The public's indifference over restraint in the use of energy and tolerance of growing economic inequities are not conducive for developing effective policies to address global warming. Consequently, it is appropriate to consider whether there are alternative approaches to the problem.

One approach is to change the public's attitudes towards energy in the U.S.A. The Marshallian perspective developed in Section 4 provides an economic explanation of why environmentalists believe that economists undervalue energy. The distinguishing feature is that Marshallian rent measures the difference between the cost of a backstop technology and the cost of production. In contrast, the conventional concern of economists is the difference between the market price and the cost of production. Historically, most of the Marshallian rent has been used to encourage consumption by charging low prices, and this in turn has led to the growth of a dispersed suburban life style in the U.S.A. Although changing public attitudes about energy is desirable, it will be a slow process even if the efforts to change attitudes are successful. More immediate action is needed.

A second approach is to use another type of environmental problem to encourage the same actions needed to address global warming. The obvious choice is to reduce urban smog. Since automobiles are a major source of air pollution in urban areas, improving transportation and reducing emissions would be desirable. A reason for expecting policies for reducing smog to be more acceptable to the public than policies for global warming is that the adverse health effects of smog are more obvious than the uncertain future effects of global warming. Improvements in fuel efficiency and public transportation would both contribute to reducing emissions of greenhouse gases.

A secondary benefit from developing new technologies for reducing urban smog in the U.S.A., such as hybrid electric buses, is that the same technologies could be used in other countries to improve urban air quality. Urban smog is a global problem, and smog in many developing countries is worse than it is in the U.S.A. Hence, there is a potential for developing new global markets for environmental technologies if governments in other countries make a commitment to internalize the external health costs of air pollution. Establishing production facilities in developing countries may be a practical way to introduce new technologies into these countries.

An effective global policy to stabilize emissions of greenhouse gases will require cooperation from a large majority of countries. A few major dissenters could jeopardize the viability of any policy. In particular, the governments of low income countries like China and India must participate because these are the countries where most of growth in emissions will occur in the future. As a practical step towards achieving this goal, it would be desirable for the U.S.A. to form a partnership with a low income country like China. (In the Reference scenario in Table 6 the forecasts of emissions in China are larger than the forecasts for the U.S.A. by the year 2015.) The objective of this partnership would be to evaluate the feasibility of different policies for stabilizing emissions. In this way, leadership would be shared between a high income and a low income country, and the knowledge about new technologies would be of value to countries at different stages of development. Other countries might form similar partnerships at the same time or choose to adopt polices on their own. Discussions among governments organized by the United Nations will continue, and they may lead to countries meeting targets for emissions in the future, unlike the current situation. Eventually, sanctions on trade for non-participating countries could be used as an incentive for limiting emissions. However, a joint commitment made by China and the U.S.A. to adopt specific actions for limiting emissions of greenhouse gases would go a long way to getting other countries to deal with the problem of global warming seriously.

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