The economic fundamentals of global warming

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Abstract

If unpriced emission of greenhouse gases imposes real costs on future generations, both present and future generations can enjoy a higher consumption of economic goods and services through the correction of this unpriced externality, so there is no real economic opportunity cost to mitigation of global warming. The misperception that control of global warming is costly rests on the mistaken assumption that the investment allocation of the world economy without mitigation measures is efficient, but in the presence of an externality the world economy is not on its efficiency frontier. Once the externality is corrected, global warming presents no novel issues of the distribution of economic welfare between generations that are not already inherent in other investment choices. The costs of greenhouse gas mitigation can be shifted to future generations by reducing conventional investment, rather than by reducing current standards of living. This suggests financing investments in greenhouse gas emission, including compensation of current generations for the necessary substitution away from carbon intensive energy, through borrowing. The question of the appropriate intergenerational discount rate to apply to the benefits of greenhouse gas emission mitigation is irrelevant to global warming policy. The relevant question is the marginal value future generations will put on a lower stock of atmospheric greenhouse gases relative to conventional capital. This value should determine the composition of the entire capital stock, including the stock of greenhouse gases, current generations bestow on the future.

1 Introduction

Human productive activities have significant effects on the global environment. The depletion of the ozone layer by the release of chlorofluorocarbons employed

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in refrigeration and propellant devices and the threat of global warming as a result of the accumulation of "greenhouse gases", carbon dioxide and methane, released in agriculture, energy generation, and transportation, are two leading examples. The emergence of these historically unprecedented impacts of human productive activity on a global scale creates an inescapable challenge to economic policy. Policies to foster economic growth, equity, trade, and technological change also have substantial impact on the unfolding of the global environmental scenario, which must therefore be taken into account in evaluating these policies. Even "doing nothing" once the impacts of economic production on the global environment has been recognized amounts to a policy choice. (See Cline, 1992, Chichilnisky, 1994, Mendelsohn et al, 1994, and Nordhaus, 2001 for a sampling of the economic literature on this issue.)

The broad framework of economic policy evaluation methods evolved over 150 years of the development of economic thought can inform these policy choices, but public and scholarly discussion of global warming often fails to apply these methods consistently. One deleterious consequence of the failure to analyze the economics of global warming correctly is the widespread, but erroneous, belief that policies to reduce greenhouse gas emission will impose a cost on the current generation, which must be weighed against the benefits future generations will enjoy from mitigation. Because greenhouse gas emissions are an unpriced economic externality, this belief is incorrect. Correcting the externality by imposing a price on greenhouse gas emissions, whether through regulation, taxation, or a system of tradable emissions permits, together with appropriate compensating measures, can increase the consumption of economic goods and services of both future and current generations.[1]

The misperception that addressing the global warming problem involves a trade-off between the standards of living of future and current generations rests on a failure to appreciate that current output, as measured by real GDP, is divided between consumption which affects the welfare of current generations, and investment in productive facilities, technology and knowledge, which increases the ability of future generations to produce. Real resources to make investments in greenhouse gas mitigation can come either from reductions in current consumption, or from reductions in conventional investments. Without some system of mitigation of greenhouse gas emissions, current generations are investing too little in mitigation and too much in conventional forms of capital. If this misallocation of investment is corrected, a net benefit will accrue to future generations, raising their welfare, *with no reduction in the consumption of the current generation.* In fact, it is possible to share this economic gain between future and current generations by increasing the consumption of the current generation at the same time that it mitigates greenhouse gas emissions, and still benefit future generations. As a practical matter, this outcome could be achieved by financing investment in greenhouse gas emission reduction, including compensation for the current generation for its reduction in consump-

[1]Throughout this paper I will assume that any impacts of the policy choices I discuss on aggregate demand will be offset by other macroeconomic policies, such as monetary policy, and do not affect the degree of utilization of productive resources.

tion of carbon intensive energy, through borrowing, which would crowd out the least profitable conventional investments and shift the burden of global warming mitigation to the future generations who will benefit from it.

Once the externality of greenhouse gas emissions has been corrected, whether through regulatory caps, carbon taxes, or a system of tradable emissions permits, global warming policy raises no intergenerational economic issues that are not already inherent in the overall decision to divide current world output between consumption and investment. Thus the question of whether a different discount rate should be applied to investments in greenhouse gas emission than to other forms of investment is economically irrelevant. What is economically relevant is the question of what price in terms of conventional investment future generations would pay for any degree of abatement of global warming, because that price determines the correct price at which current investments in greenhouse gas abatement should be valued. The more we think future generations value abatement of global warming, the larger should be the share of investments in greenhouse gas abatement the current generation bequeaths to them.

2 The economic analytics of global warming

The essential economic elements of the global warming scenario can be expressed in a simple economic model involving four elements: the consumption of the present generation, C, the consumption of future generations, F, the *conventional capital stock* resulting from the investment of the current generation, K, and the *climatological capital stock* representing the reduction in the stock of greenhouse gases in the atmosphere due to investments of the current generation in the mitigation of global warming, E. It is reasonable to suppose that there are tradeoffs between the consumption of each generation and the capital stocks, so that in mathematical terms C and F are functions of K and E. The consumption of the current generation declines with increases in K and E because both conventional and climatological investment require the diversion of real resources from consumption, while the consumption of the future generation (including its ability to make provisions for yet further generations) increases with K and E because the more conventional capital and the lower environmental damage from global warming, the more future generations can produce and consume.

For the moment let us consider the consumption level of the current generation, C, as fixed at its actual level $\bar{C}$. There is a menu of combinations of K and E that are consistent with this level of consumption. Since at present the world economy puts close to a zero price on investment in E, the level of E it is bequeathing to future generations is very low. Furthermore, the marginal reduction in K required to increase E is very low as well. But if the threat of global warming is real, the consumption of future generations, F, could be raised by lowering K and increasing E. The marginal cost of increasing E in terms of K foregone is less than the marginal benefit of increasing E and lowering K to the consumption of future generations. Thus it would benefit future generations to

divert resources from conventional investment, K, to climatological investment, E. Such a diversion would leave the consumption of the current generation unchanged, and would increase the consumption of future generations. There is *no trade-off* between C and F until investment in E has reached the point where its marginal cost in terms of K equals its marginal benefit in raising the consumption possibilities of future generations.

Figure 1 illustrates this point.

3 Mitigation strategies

The efficient level of investment in mitigation the current generation should aim for is uncertain, due to uncertainties in the costs and benefits of various mitigation strategies. (If there is any global warming problem to begin with, however, it is certain that some level of mitigation is called for.) Policy makers, in setting a level of carbon taxes or a cap on greenhouse gas emissions, have to estimate how much future generations would be willing to pay in terms of conventional investment to inherit any given level of reduction in global warming. (The timing of investments in mitigation raises more complex technical questions, but does not alter the fundamental economic point that there is no tradeoff involved in correcting an existing externality.) There is bound to be controversy over the magnitude of this willingness to pay, but this controversy should not obscure the fact that what is at issue is the distribution of a potential net benefit between generations, not the distribution of a net cost. The problem is to approximate the efficient composition of the investment portfolio the current generation leaves to future generations between conventional and climatological investments.

As long as the real resource costs of mitigation of global warming are paid out of conventional investment, the cost of errors of over- or under-investment in mitigation will be borne by future generations. One way to protect the consumption of the current generation is to finance mitigation, including the cost of compensation to the current generation, by borrowing. Borrowing to finance global warming mitigation will raise interest rates and crowd out marginal conventional investment, thus ensuring that the resources required for mitigation come from conventional investment, not current consumption. The finance of mitigation by borrowing also ensures that the monetary costs of mitigation will be paid by future generations, who will also be the main beneficiaries of climatological investment.

4 Intergenerational equity and time-discounting

Except for the externality that under-values investment in greenhouse gas reduction, there is no difference between climatological investment and conventional investment in their impact on the distribution of economic welfare between current and future generations. The issue of generational distribution concerns

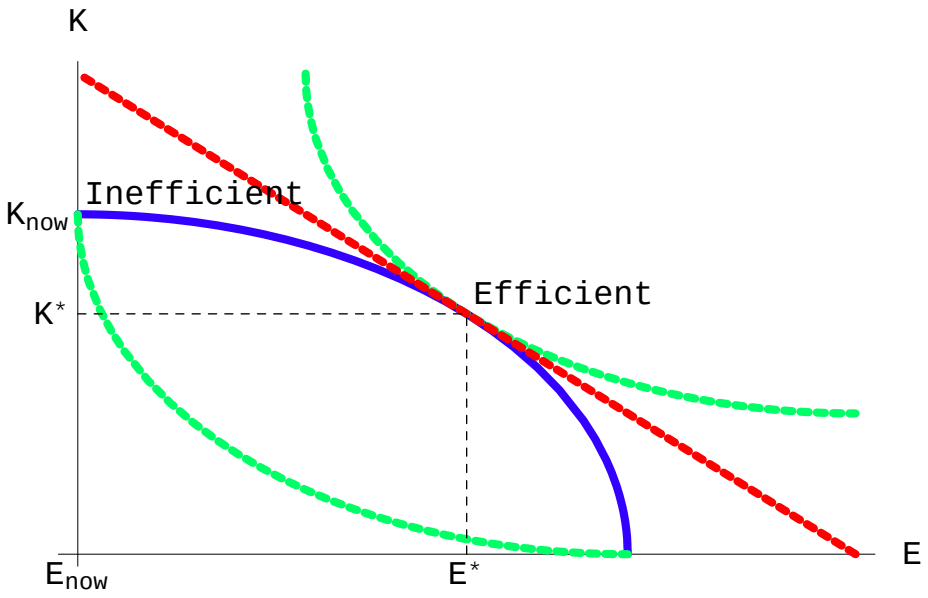

Figure 1: The heavy line represents combinations of E and K compatible with the present level of consumption of the current generation. Without mitigation of global warming the current generation will bequeath effectively zero climatological capital to future generations represented by the point (E_{now}, K_{now}). The lower dotted curve shows the combinations of E and K that would allow future generations to achieve the same level of consumption. Because the marginal cost of mitigation at the original point is zero, but the marginal benefit of mitigation for future generations is positive, the current allocation is inefficient. It would be possible without reducing the consumption of the current generation to move to (or closer to) the efficient allocation of investment, (E^*, K^*), at which future generations could enjoy a higher level of consumption. At the efficient point the marginal cost and benefit of mitigation in terms of conventional investment are equal.

the overall size of the investment the current generation makes. There is nothing special about the investment the current generation might make in global warming abatement that requires a separate intergenerational equity discussion centered on this point.

When the global-warming externality is uncorrected, the world allocation of consumption between current and future generations is inefficient. The correction of the externality permits an increase in consumption of both current and future generations. The exact division of this increase between current and future generations will depend on the value the current generation puts on future generations' consumption. Figure 2 illustrates this point.

Many economic discussions of global warming mitigation, including the "Stern Review" (Stern, 2006) and comments on it (Nordhaus, 2006, Dasgupta, 2006), seem implicitly to consider investment in global warming mitigation as an addition to whatever conventional investment the current generation is making. It is only from this point of view that it makes sense to calculate the balance between intergenerational costs and benefits using a pure intertemporal discount rate. If the level of current conventional investment is taken as a constraint in deciding global warming mitigation policy, then the resource costs of the investment in greenhouse gas emissions would have to be borne by the consumption of current generations. In this case it would be necessary to consider intergenerational consumption tradeoffs. But why should the current level of conventional investment be taken as a constraint in analyzing the mitigation of global warming? This presumption obscures the key point that correcting the greenhouse gas externality can improve the consumption possibilities for future generations without reducing the consumption of current generations at all. In assuming that mitigation must be financed from current consumption, this type of economic analysis implicitly biases its conclusions against climatological investment.

If the correction of the greenhouse gas externality raised the whole future path of world income substantially, there would be a case for redistributing this benefit by overcompensating the current generation for its reduction in emission of greenhouse gases with other types of consumption. Some degree of overcompensation is probably desirable in any case to allow for errors in the compensation scheme and to create political support for mitigation policy. But it would only be in the context of this second-order adjustment that the questions of intergenerational equity and time-discounting would become relevant. Since the allocation of welfare between current and future generations is already affected by conventional investment policy, the global warming problem introduces no novel considerations in this discussion.

5 Financing climatological investment

As the analysis above shows, the key economic point is that the appropriate level of mitigation of global warming can be achieved without cost to the current generation, if the resources used to achieve mitigation come from investment rather

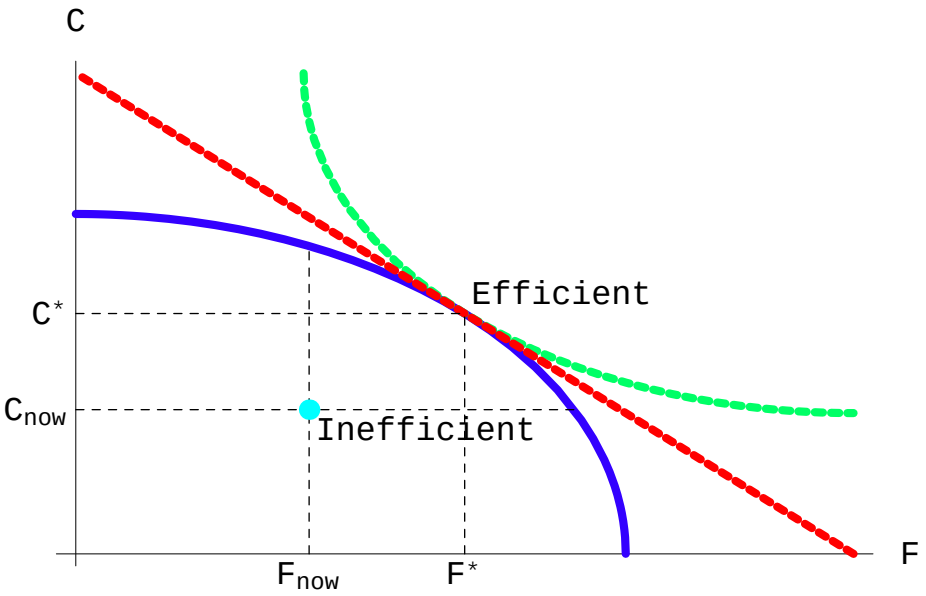

Figure 2: The heavy line represents combinations of F and C compatible with the technological tradeoffs between consumption of current and future generations, taking account of both conventional and environmental investments. Without mitigation of global warming the point representing the consumption of future and current generations is inside this frontier, (F_{now}, C_{now}). Correction of the global-warming externality would move the world to (or closer to) the efficiency frontier. One possible efficient allocation is shown as (F^*, C^*). The exact division of the benefit of correcting the externality between future and current generations will depend on the marginal valuation current generations put on the consumption of future generations, represented by the slope of the dotted line tangent to the efficiency frontier.

than consumption. The fact that the benefits of investment in mitigation of global warming will accrue largely on a time scale longer than the payoff of most conventional investments makes no difference to this logic. Consider an intermediate generation, which does not benefit much (or at all) from mitigation, between the current generation which invests in mitigation and a distant future generation that benefits from mitigation. If the current generation invests less in conventional capital, the intermediate generation will produce a smaller output than it would have with a larger conventional capital stock, but need not have a lower standard of living if it consumes a larger proportion of that smaller output by restricting its conventional investment. The distant future generation will inherit a smaller conventional capital stock from the intermediate generation, but will be more than compensated by the larger environmental capital representing reduced global warming.

How does this logic play out in terms of actual economic policy and behavior?

Whether greenhouse gas emissions are reduced as a result of direct regulation, carbon taxes, or a tradable system of emissions permits, the economic effect of mitigation will be to raise the real price of carbon-intensive energy to current users (and reduce the incomes of owners of carbon-intensive energy resources). This change in and of itself clearly imposes real costs in terms of standard of living and consumption on current users. In order to hold the current generation harmless in the face of this change it is necessary to compensate them with higher consumption of non-carbon intensive consumption. The political problem is how to fashion such a compensation system and educate the public to realize that they will directly benefit from the combination of greenhouse gas mitigation and the compensation measures. There is no point in refunding the higher price of carbon-intensive energy at the pump, so to speak, since that would remove the incentive effects to reduce emissions which are the point of the policy to begin with. The users of carbon-intensive energy have to be compensated through some other channel.

Economic theory suggests "lump-sum" transfers as the ideal method of compensation for the costs imposed by correcting a production externality. It would in theory be possible to compensate current energy users for an increase in carbon-intensive energy prices by a combination of increases in public expenditures for education, health care, and transportation combined with general reduction in income, property, sales, and employment taxes, for example. Some methods of reducing carbon-intensive energy, such as a carbon tax, would generate some revenue to offset these expenditure and tax changes. The remaining revenue shortfall could and should be met by borrowing, which would have a solid economic justification as a method of shifting the real costs of mitigation to the future generations that would reap its benefits. The traditional economic argument against debt finance is that borrowing "crowds out" conventional investment by raising the interest rate. But in the case of global warming mitigation, the crowding out of conventional investment is exactly what is called for. The mitigation of greenhouse gas emissions, far from being a potential drain on the public finances, actually represents a potentially large additional revenue source.

There is no economic logic supporting proposals to link reduction of greenhouse gas emission through an increase in carbon-intensive energy prices to any particular expenditure increase or tax reduction, such as subsidies to non-carbon intensive energy technologies. If prices of carbon-intensive energy rise to reflect the real opportunity cost of global warming to future generations, this in itself will provide the appropriate incentives for investments in alternative energy technologies.

As a practical political matter, it is desirable that the package of changes in expenditures and taxes that accompanies greenhouse gas mitigation come as close as possible to compensating (or somewhat over-compensating) all the citizens who will be disadvantaged by an increase in carbon-intensive energy prices. There are bound to be "hardship" cases where the increase in carbon-intensive energy prices imposes unusually high costs on individuals, or even communities. Some safety-valve mechanism for compensating credible hardships is a desirable part of the policy package.

The economic policy discussion on climate change has focused on the undoubtedly important question of mechanisms for controlling greenhouse gas emissions, such as direct controls, a carbon tax, or cap-and-trade markets for emission permits. Because these measures all impose the same real resource costs on current users of carbon-intensive energy to achieve any level of global warming mitigation, they all raise the same broader question of how to compensate the current generation for its environmental investment. In principle compensation can be achieved by diverting resources from conventional investments; the task is to unpack this insight into transparent policy proposals that would convey to politicians and their constituencies the economic substance of the global warming problem.

6 Political resistance to costless economic policy measures

The widespread resistance on the part of some politicians and pundits to investing real resources in effective mitigation of global warming reminds us that the analysis presented here is not universally understood, and that the premises of the argument are not universally accepted.

The argument for reducing greenhouse gas emissions rests on the twin premises that reduction of atmospheric greenhouse gas concentrations will lower future global temperatures, and that higher future global temperatures will impose real costs on future generations. These two premises imply the conclusion that greenhouse gas emissions are a real uncorrected economic externality that is preventing the world economy from reaching its efficiency frontier. Presumably political opposition to correcting the externality must rest either on a judgment that greenhouse gas concentrations have no predictable effect on global temperatures, or that future generations would be better off with higher global temperatures. The scientific case that there is some impact of greenhouse gases

on global warming is very strong. Those who accept this science and still oppose mitigation must therefore believe that global warming is a good thing, which would imply a policy of increasing greenhouse gas emissions.

The possibility of economic misunderstanding by politicians is ever-present, as even a cursory study of economic policy-making will confirm. The resistance to investing in mitigation of global warming is most often expressed on the grounds that the resources diverted to mitigation would reduce "economic growth". The present analysis makes clear that this is simply not true. Mitigation changes the composition, but not the aggregate amount, of investment. It is hard to imagine what measure of economic growth would fail to acknowledge the increase in consumption possibilities for future generations made possible by correcting the greenhouse gas externality.

One possible misunderstanding is simply that politicians who talk this way are victims of "conventional real GDP illusion", in that they have been so mesmerized by economists' fixation on real GDP growth as currently measured that they cannot imagine incorporating the benefits of global warming in their economic thinking. The only cure for this type of illusion is for economists to be more careful in explaining the relationship between particular definitions of real GDP and economic growth and welfare.

Politicians may also be particularly sensitive to the collective action aspect of global warming mitigation. Since any reduction in emissions will reduce the global stock of greenhouse gases, it is true that any one region of the planet benefits substantially from other regions' mitigation efforts. But the basic economic logic of the correction of an externality applies even to individual regions' investments. Any mitigation a region accomplishes will benefit that region to some degree (less, to be sure than if all other regions made the same effort, but still conferring a positive economic benefit). Thus one would expect that the collective action aspect of the global warming problem might slow, but would not block, individual regional investment in mitigation. (Indeed there are signs that this point has dawned on policymakers in some regions, and even large corporations, which have unilaterally begun to make investments in mitigation, presumably reflecting their private calculation of a net benefit.)

It is also possible that the political system functions badly on this issue, in that disagreements over the distribution of the net gains from correcting the global warming externality will prevent us from achieving any gain at all. The correct economic analysis of the global warming problem, however, suggests that it is not properly speaking a political issue at all, and that ideology and partisanship have little relevance to it.

The analysis presented here suggests that the prospects for actually doing something about the global warming problem are good. We have recognized the issue in time to do something about it, and we have methods and resources to mitigate global warming. Because the reduction of greenhouse gas emissions financed by an economically appropriate reduction in conventional investments can benefit future generations with no reduction in the overall consumption of the current generation, there is appears to be no real insurmountable political obstacle to a world-wide system of mitigation.

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