THE ANCILLARY BENEFITS AND COSTS OF CLIMATE CHANGE MITIGATION: A CONCEPTUAL FRAMEWORK

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1. Introduction

Within the broad set of climate change issues, one that is growing in controversy and potential importance is the ancillary benefits and costs of policies to reduce greenhouse gases (GHGs). Ancillary benefits and costs are externalities arising from GHG abatement policies that are achieved jointly with the reduction of GHGs in the atmosphere.[1] Analysts have attempted to identify and in some cases to estimate these benefits, with estimates ranging from a small fraction of GHG mitigation costs to largely offsetting them.[2]

In this paper, we demonstrate and emphasize that such a variation in estimates should be expected, and indeed is a requisite criterion for the studies to be considered credible as a group. But, definitions, underlying assumptions, modeling procedures and parameters have all varied, rendering comparisons and analysis unnecessarily difficult, and under mining the quality of the studies considered individually. We articulate a principle to improve the quality of this literature: in different applications, *methods should be consistent and estimates should not*. The field needs an overarching conceptual framework, to provide guidance on how to achieve methodological consistency across studies and to help achieve a consensus with regard to how the results can be interpreted, and incorporated in climate policy discussions. Our paper begins to build this framework.

A great deal is at stake in how this controversy is decided. If these ancillary benefits are significant, or the distribution of ancillary benefits is expected to be spatially concentrated, then perhaps the development and implementation of climate policy should be altered. At the very least, knowing that the possibly high cost of climate change mitigation might be largely offset by ancillary benefits could speed up and spread the commitment to action as well as implementation itself. On the other hand, if these effects are "small" relative to the other costs or the benefits of reducing GHGs, perhaps they can be safely ignored in the debate over climate change mitigation policy — at least from the perspective of efficiency — simplifying an already too complex debate.

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1. Nomenclature for this issue is still evolving. We use ancillary benefits and costs to refer to monetized effects of GHG policies. "Co-benefits" is another term in the literature. We reserve this term for the benefits of policies, say for the reduction of conventional air pollutants, that are coordinated with a climate change mitigation policy. "Ancillary impacts" refer to ancillary physical effects. Unless otherwise made clear in the text, "ancillary benefits" also refers to "negative benefits, i.e., "ancillary costs."

2. See Burtraw *et al.* (1999) and reviews by Pearce (2000); Burtraw and Toman (1997); Ekins (1996).

Although there are a number of difficult issues that have to be addressed, fortunately, the issues surrounding analysis of ancillary benefits are *not* the same order of complexity as issues surrounding the analysis of climate change generally. It is widely acknowledged that climate change is a phenomenon that transcends generations and cultures, with dramatically differing potential impacts on various peoples and countries. This, coupled with a tremendous heterogeneity in the sources of emissions and the wealth of nations, all of which are expected to change over time, raises what are perhaps the most complicated issues in economics and philosophy that our global society has ever faced.

Many of these issues do not have to be faced in the context of ancillary benefits. Most of the key ancillary costs and benefits are relatively *short-term* and most of the benefits are '*local*' -i.e. they affect the communities relatively close to the source of the policy or program. In both these respects ancillary benefits and costs are very different from the benefits of climate policy, which occur over decades and which have an effect at a global level. However, they are similar and easily compared to the cost of climate policy, which occur locally to jurisdictions making policy.

The advantage of being able to deal with ancillary costs and benefits as local rather than global should not be underestimated. When this is the case, the dramatic cross-country differences in income and ability to pay that plague benefit-cost analysis when applied in an international setting become largely irrelevant. What matters then is the local opportunity cost of climate mitigation compared, in part, to local preferences for better health and other environmental improvements. These opportunity costs will be larger in wealthier nations than poorer ones, but so will the ancillary benefits and costs. In either type of country, they can guide efficient resource allocation and act as a useful input into climate policy decisions.

Furthermore, troubling questions of how to deal with intergeneration and international equity are omnipresent in climate discussions, but they are largely irrelevant for the calculation of ancillary benefits. The ancillary benefits stemming from reductions in conventional pollutants largely accrue in the same timeframe as when cost of climate polices are incurred. (Costs also may be incurred in the future due to different rates of saving and economic growth that result from climate policy). Handily, ancillary benefits can often be offset in a meaningful calculus with costs when considering climate policy without delving into questions of discounting benefits and costs that accrue in the future.

We acknowledge that some ancillary benefits have lasting or long-term implications, such as changes in acidification of ecological systems. In these cases, intergenerational issues remain relevant. However, as many studies have indicated, the lion's share of quantified benefits from reductions in conventional pollutants can be expected in the air-health pathways. Other areas that also have been found important in previous studies, such as transportation-related externalities, also accrue in the present.

We also acknowledge that atmospheric transport of pollution is important, and transport crosses over boundaries separating economies and societies that have different wealth and culture. Usually, however, the dispersion of conventional pollutants is regional or local in nature, and usually at the regional level the similarities outweigh the differences among affected countries, especially when compared to global diversity. Counter examples may be found in Eastern Europe, Southeast Asia and elsewhere, but these do not constitute the major considerations to be faced. Further, global analysis of ancillary benefits has a value in illustrating the potential magnitude of these effects and to ignite interest by researchers and international agencies in the issue.[3] Indeed, we rely on analysis at the

[3] Davis, *et al.* (1997).

global level to illustrate the possibility of leakage of carbon emissions. However, global modeling and analysis is necessarily weak in describing the institutional setting at the national or sub-national level that plays prominently in the realization of ancillary benefits in practice.

We remain agnostic about the potential ways in which information about ancillary benefits may be used, but the intent for how these estimates will be used will affect the value of additional information, the level of detail and the allocation or resources over aspects of the study. One can imagine ordering possible policy responses to a finding of large ancillary benefits from least to most interventionist. The least, and the one favored by Pearce (2000), is to simply use the existence of large ancillary benefits as an additional rhetorical "no regrets" argument in favor of action on climate change — particularly since such benefits will be experienced in the same time frame as costs. Somewhat more interventionist is to argue for a speedup of climate policy implementation or a spread to additional countries. In developing countries, the consideration of ancillary benefits may affect both the willingness to enter the international control regime and the level of participation.

More interventionist still would be to make the carbon reduction target or the tax more stringent, in light of the greater marginal benefits to be derived for the same marginal cost. Finally, the most interventionist approach would be the idea that the character, perhaps in addition to the stringency, of climate mitigation policy would be affected. If ancillary benefits are significant, it could make sense – say under a carbon trading regime — to concentrate carbon reductions in areas or sectors affecting the most people, holding the carbon reduction target constant. In this way ancillary benefits could be maximized for meeting the given carbon reduction target.

There are a variety of ways that this could be implemented, and a variety of challenges in targeting carbon reduction in this way. The approach depends on the type of carbon policies that are implemented. Under a carbon permit trading system, one way to do this would be to alter the initial allocation of carbon permits with an eye towards maximizing ancillary benefits. A carbon tax system could be designed to spatially or sectorally differentiate taxes to get the most ancillary benefits bang for the carbon reduction buck, again, with an eye to meeting the same carbon reduction (or incurring the same aggregate cost). Under the patchwork of policies that many nations are likely to implement, the consideration of ancillary benefits could play as one factor in the determination of relative burden that will be imposed upon various sectors or regions.

To summarize, we feel the heart of the analysis of ancillary benefits involves the *here and now* that is relevant to individual policy makers in a national context. In this paper we concentrate on the issues and methods we think most important in identifying and measuring ancillary benefits and costs in order to inform national-level policy analysis regarding GHG mitigation. These issues include: (i) consistent definition of costs and benefits, and an illustration of the variety of possible ancillary benefits; (ii) identification of the pollution, policy and population baselines for GHG policies; (iii) description of methods and identification of research breakthroughs that could alter conventional wisdom on the size of these benefits; (iv) the identification of possible ancillary costs of climate change mitigation; (v) identification of the proper scale and scope, and treatment of uncertainty in modeling of economic behavior and physical processes; and, (vi) special considerations in a developing country setting.

2. Types of externalities

2.1 Definition

Externalities may arise when economic activity has effects on third parties. However, all impacts on third parties may not necessarily be externalities. Such effects may be viewed from a variety of perspectives, including, especially, the perspective of someone who is harmed. However, the term "externalities" applies to an economic analysis focused primarily on an efficiency perspective. We are interested in cases when a policy yields a change in the *productive* use of resources, or in the *welfare* of individuals, and when these effects are not fully taken into account by the agents involved. The magnitude of an externality can be measured by comparing the difference between the *social opportunity cost* of resources that are used in production, and the *private market cost* of those resources.

The focus on ancillary effects means we are focused on effects other than the reduction in GHG emissions, but which occur indirectly as a consequence of those reductions. The Appendix to this paper provides a thorough discussion of the economic concepts involved in identifying externalities, and more complete definitions of some of the terms used in this paper. A couple of the main points to appreciate are the following.

First, externalities do not necessarily arise when there are effects on third parties. In some cases, these effects may already be recognized in, or "internal to," the price of goods and services. Consider a stylized example, such as damages to vehicles in an automobile accident. If each driver is fully liable for damages to other vehicles and one can reliably assess fault and enforce liability, then the damage in an accident would not be an externality because the party at fault would fully recognize the costs. In this case behavior should reflect the possibility of an accident, *ex ante*, and behavior should be "efficient," even though accidents would occur with a probability greater than zero. Moreover, one can see a variety of justifications for considering externalities in this example. If drivers are not fully liable, or if fault could not be established, or if liability was not enforceable, then the behavior of one driver could not be expected to fully reflect potential damage to others. Any of these exceptions provide a justification for treating the damage to vehicles in the example as an externality. The key idea to note is that such exceptions constitute a deviation from ideal institutions. In economic vocabulary, this is referred to as *market failure*. For damage to be considered an externality from the viewpoint of economic efficiency, one should be able to identify some kind of failure in markets or other institutions that causes individuals to fail to take into account the social costs and benefits of their individual actions. From a practical perspective, it is also important that such failures result in an important misallocation of resources.

A second point to appreciate is that the economic accounting of externalities does not hinge on the provision of compensation. In fact, there is a reason to deny the provision of compensation (though this remains a controversial point in benefit-cost analysis), because the potentially harmed party may have inadequate incentive to "take care" if compensation is guaranteed. Hence, efficiency analysis leads to findings that may seem irrelevant from an equity standpoint, and *vice versa*. Nonetheless, equity considerations remain important in their own right. Successful public policy must weave together both efficiency and equity considerations.

2.2 A partial taxonomy

There are a variety of effects that may result from GHG policies that are secondary to the reduction in GHG emissions. For example, existing studies have identified mortality and morbidity benefits associated with collateral reductions in particulates, nitrogen dioxides and sulfur dioxides from power plants and mobile sources as a major source of ancillary benefits. Additional areas that might be considered include improvements in ecosystem health (for instance, from reduction in nitrate deposition to estuaries), visibility improvements, reduced materials damages, and reduced crop damages. Reduced private auto use and substitution of mass transit will reduce air pollution and congestion and may also reduce transportation-related fatalities from accidents, although the size of this effect and the degree to which it would count as an ancillary benefit are unclear.[4]

At the same time, there may be ancillary costs of GHG mitigation, such as an increase in indoor air pollution associated with a switch from electricity to household energy sources (such as wood or lignite) or greater reliance on nuclear power with its attendant externalities. In developing countries pollution may rise if electrification slows as a result of policy-induced increases in electricity prices. A related cost would stem from foregoing the benefits of electrification, which include increased productive efficiency and emergence of new technologies, to increases in literacy (Schurr, 1984).

The following offers an illustrative set of examples and an indication about whether they are potential ancillary benefits (+) or costs (-). Note that under certain conditions, any of these observed impacts would not necessarily count as externalities from the standpoint of economic efficiency, depending on whether market or institutions fail to account for these impacts in the incentives they provide for individual behavior.

- Reduction in particle pollution when fossil fuel use is reduced (+).
- Increased availability of recreational sites when reforestation programs are introduced (+).
- Increases in household air pollution relative to a baseline when electrification rates are reduced (-).
- Increases in technological efficiency when new technologies are adopted and unit costs fall (+).
- Increases in welfare when a shift to carbon taxation and a reduction in reduces unemployment (+).
- Reductions in road-use related mortality when a shift from private to public transport takes place (+).
- Reductions in congestion when a shift from private to public transport takes place (+).
- Increases in employment resulting from GHG projects where there is excess supply of labor (+).

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4 It is noteworthy that a major study in the early 1990s that considered externalities throughout various fuel cycles for electricity generation in the US concluded that among the single highest valued endpoints (among many specifically defined endpoints) were fatalities associated with rail transport of coal and damage to roadway surfaces beyond those internalized in road fees (Lee *et al.* 1995).

– Decline in employment due to decreased economic activity resulting from costs associated with GHG projects (-).

– Savings in household time in poor rural households when fuel wood use is replaced by renewable energy (+).

– Reductions in electricity use resulting from higher electricity prices that cause less use and thereby reduce educational opportunities for children (-).

A taxonomy of the main externalities from air pollution, that were developed in the social cost of electricity studies and that are likely to be relevant to ancillary benefit estimation is provided in Table 1. Note also that not all the impacts can be quantified in monetary terms, although we believe them to be potentially important. The cases that are only partially quantified are indicated by an 'AP'. In addition there are other impacts that have not been quantified at all. We simply do not know whether they are important or not. They have been indicated by an 'NA'. Examples of 'AP' include many impacts on eco-systems, and material damages to cultural buildings. Examples of NA impacts include ozone on forests and heavy metals on eco-systems.

Table 1. A sample of externalities assessed in studies of electricity generation

	Health		**Materials**	**Crops**	**Forests**		**Amenity 2/**	**Eco-Systems**
	Mortality	**Morbidity**			**Timber**	**Other**		
PM_{10}	AM	AM	AP	n.e.	n.e.	n.e.	AM	n.e.
SO_2 1/	AM	AM	AP	AM	AM	AP	AM	AP
NO_x 1/	AM	AM	AP	AM	AM	NA	n.e.	AP
Ozone	AM	AM	AP	AM	NA	NA	n.e.	n.e.
Mercury and other heavy metals	AP	AP	n.e.	n.e.	n.e.	n.e.	n.e.	NA
Routine 3/ Operations	AM	AM	n.e.	n.e.	n.e.	n.e.	n.e.	n.e.
Water pollutants4/	n.e.	n.e.	n.e.	n.e.	n.e.	n.e.	AP	AP
Noise	n.e.	NA	n.e.	n.e.	n.e.	n.e.	AM	n.e.

Source: Developed from Markandya and Pavan, 1999.

Notes:

AM: Assessed in monetary terms, at least in some studies.

AP: Assessed in physical terms and possibly partly in monetary terms.

NA: Not assessed, although we believe they may be important.

ne No effect of significance is anticipated.

1. SO_2 and NO_x include acid deposition impacts.
2. Effects of $PM_{10,}$ NO_x and SO_2 on amenity arise with respect to visibility. In previous studies these have not been found to be significance in Europe, although they are important in the US.
3. Routine operations generate externalities through mining accidents, transport accidents, power generation accidents, construction and dismantling accidents and occupation health impacts. All these involve mortality and morbidity effects.
4. Water pollution effects include impacts of mining (including solid wastes) on ground and surface water, power plant emissions to water bodies, acid deposition and its impacts on lakes and rivers (partly quantified).

2.3 *Issues in taxonomy of ancillary effects and the mapping to externalities*

Some of the effects listed above are not externalities in the pure sense, or in every instance when they are observed. An example is employment effects. Employment decisions might be regarded as properly the domain of private decision-making. However, consideration of changes in employment, from an efficiency perspective, is justified in cases when there exist (a) poor information and (b) limited possibilities for these benefits to be represented through market prices.

A comprehensive taxonomy of environmental, public health, agriculture, land use and economic impacts that may qualify as externalities for the purpose of measuring ancillary benefits has been developed in at least three recent studies (Lee et al, 1995; Hagler-Bailly 1995; European Commission 1999). These studies each looked at full fuel cycles associated with electricity generation. The range of effects legitimately range from health and safety issues, to ecological issues and even to economic issues. Many effects map to externalities in a fairly straightforward way; this is certainly true for public health impacts of changes in conventional air pollutants, which are likely to be the single most important category according to these previous studies. However, each impact requires an assessment of whether it qualifies as an externality according to the definitions and criteria we have laid out in this section and the appendix. We illustrate this further with four examples of cases when effects may not qualify as externalities.

1. *Occupational health and safety:* Changes in the use of fuels will have implications for the number and severity of workplace injuries. However, there are pre-existing mechanisms through which such injuries may be at least partially internalized in product prices. One way may be through the liability of employers. If workers have the right to sue for compensation for injury then employers must bear some portion of the cost of injuries, and this provides some incentive on their part to reduce workplace risk. Also, wages are likely to vary among employment categories reflecting in part the variation in workplace risk and working conditions. This also serves to internalize some or all of the effect on workers. Consequently, if changes in fuel use lead to a reduction in workplace injury associated with one fuel cycle, this reduction may not necessarily count as an economic externality. The degree to which it should do so is likely to vary across countries and industries.

2. *Employment changes:* Changes in fuel use have the potential to reduce jobs in a sector or region of the country resulting in temporary unemployment and transition costs. These changes may not constitute externalities, however. In a fully employed economy, resources will rapidly be transferred to new use. For employment changes to be viewed as externalities, Lee *et al.* 1995 show that these changes must occur in a region that has persistent unemployment due to some type of failure in labor markets. Even in a fully employed economy, the loss of "social capital" and other types of transitional costs can incur resource costs. The degree to which employment changes should be viewed as externalities hinges on a detailed assessment of the labor markets that are affected by a policy.

3. *Energy security:* Guaranteeing a reliable source of energy has been a central objective of national governments throughout the last century. However, most of the justification for concerns about energy security has stemmed from events outside the normal operation of markets, including cartel behavior and war. Even in the case of supply disruptions, it is well established that a major portion of the resulting economic cost was due to the response of affected countries to supply disruptions, rather than to the actual disruption of energy supply (Bohi, 1984). Furthermore, though the cost of military interventions to

maintain oil supply lines has been substantial, it would not be appropriate to apportion this cost to marginal changes in fuel use because they were largely a fixed cost, with precedent relevant to a variety of contexts. How to analyze energy security is largely a strategic issue, but not one that lends itself well to economic analysis, in our view.

4. *Induced technological change.* Induced technological change may or may not be an example of an ancillary benefit. The important principle is consistency in order to avoid double-counting. If technological change is a benefit, the opportunity cost of redirecting resources in new technological directions has a cost that can be significant (Goulder and Schneider, 1996). This cost stems from the loss of value from research and development that was foregone that would have occurred in the absence of the GHG policy and would have yielded a different set of social benefits.

2.4 Issues in framing the analysis of ancillary benefits

This section introduces two additional issues that would characterize a thorough analysis of ancillary benefits and presents an overall framework for their estimation in graphical form.

2.4.1 Ancillary benefits legitimately vary under alternative climate change mitigation policies

Estimates of ancillary benefits may vary significantly in different studies or under different GHG policies due to the type of climate change mitigation policy being considered. This can make it difficult to discuss ancillary benefit estimates without qualifying the estimates according to the GHG policy context. Furthermore, when estimates vary, it allows for confusion and provides an opportunity for critics to question the reliability of the methods. However, such variance in estimates may be **legitimate**, and indeed may be a necessary criterion as a measure of the rigor of the methods that are used.

For instance, imagine a policy in the US that targeted the use of coal in electricity generation. This information alone does not provide a meaningful context for evaluation of ancillary benefits, because the policy could have a variety of impacts with respect to emissions of conventional pollutants. If the policy imposed a moratorium on coal development, something that would be sure to have its supporters, it would have a very different effect than a policy that sought to shut down older and less efficient coal-fired power plants. Rowe, Smolinsky, and Lang (1996) point out that emission rates at coal plants in New York State can vary by up to an order of magnitude, depending on their vintage. Heat rates at these plants, which would determine their carbon emissions, are likely to vary by a factor of 2:3. Hence, the change in conventional pollutants per ton of carbon reduced may vary by a factor of six between these two types of policies if they were applied in New York State. If one considers the geographic location of emissions from a national perspective, the likely location of a displaced new plant would affect a rural population with density just a fraction of that in New England. Hence, the ancillary benefits of these two polices may vary by an order of magnitude.

2.4.2 Tax and regulatory interaction effects

When markets are distorted away from economic efficiency, due to pre-existing taxes or other regulations, the cost of new regulatory policy is affected. The cost of policy (and perhaps the benefit) is likely to be considerably greater than would be indicated by an analysis that does not recognize these pre-existing features of the economy.[5] Most economists would call this a **direct** (though often unmeasured) economic cost of regulatory policy, and not an ancillary cost.

The relevance of interaction effects to the measure of **ancillary benefits or costs** is two-fold. First, if these costs are excluded from benefit-cost analysis of GHG policies, then they should be accounted for in ancillary benefit studies.[6] Second, these economic costs are not only a characteristic of the GHG policies, but they also characterize other environmental policies in the regulatory baseline. Climate change policy may affect the cost of existing regulation. If the cost of attaining non-climate regulatory goals falls, with it will fall the cost of the tax interaction effect, thereby magnifying the cost savings.[7]

The magnitude of the interaction effect hinges importantly on the type of policy instrument that is used for achieving climate goals. For instance, a carbon tax generates revenues that can be used to offset pre-existing taxes, thereby lessening distortions associated with a new tax or regulation, but typically not erasing them. Estimates of the cost of carbon taxes that include the interaction effect are typically 30 per cent greater than would be estimated if the interaction effect was ignored. A system of tradable permits with permits allocated without charge (grandfathered) can be dramatically more expensive. This is because grandfathered permits impose a cost through interaction with preexisting taxes just as would an environmental tax, but they does not raise revenues that can be used to lessen pre-existing taxes (Goulder, Parry and Williams, 1998). Other authors obtain a lower economic cost if the revenues recovered from a carbon tax are directly specifically toward reform of the most distorting taxes (Jorgenson *et al.* 1995).

The magnitude of interaction effects also depends importantly on the national setting. For instance, Bye and Nyborg (1999) find, for Norway, that the recycling of revenue from a carbon tax can nearly outweigh the cost associated with the tax-interaction effect. The existing literature applies to the US and nations in Europe. Differing rates of unemployment, taxation, and various regulations affecting factor markets affect the results. The measurement of interaction effects in less developed nations is likely to be much more difficult and is a forefront topic in economic research.

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5 Parry (1995), Goulder (1995). Williams (1999) points out benefits may be greater too.

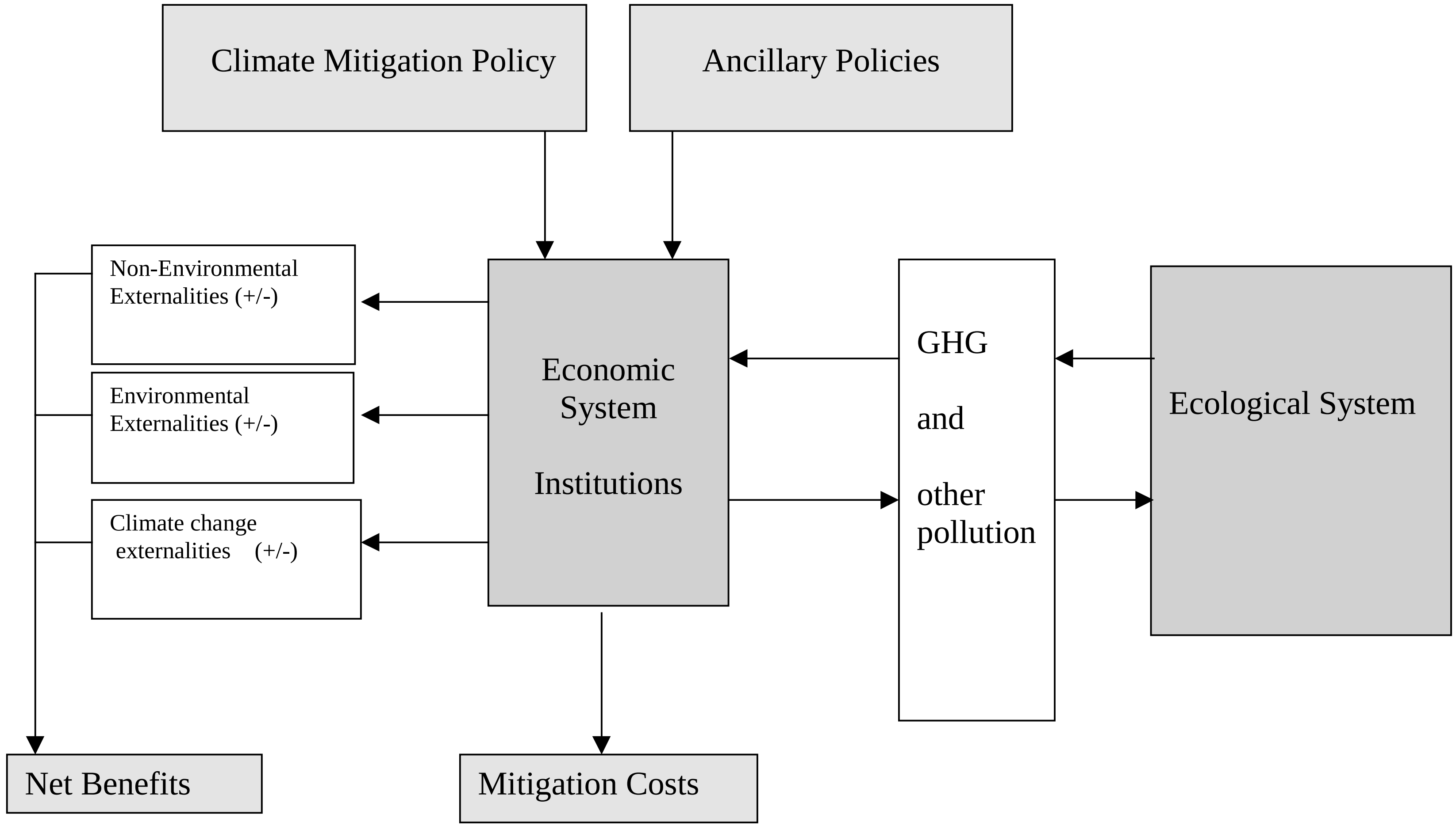
6 An important measure of tax losses is through the marginal cost of public funds literature. If a mitigation program is funded through increased taxation, or reduces the present burden of taxation, it has a welfare effect measured by the marginal cost of public funds times the changes in taxes. The theoretical discussion of the marginal cost of public funds is surveyed by Hakonsen (1997). Empirical estimates of the marginal costs have been made by the World Bank and others (World Bank, 1997; European Commission, 1998). The EC uses a value of 1.28 for the shadow price of public funds. A similar value will be valid for other OECD countries, but it is likely, however, that a higher value will prevail for developing countries.

7 For instance, Goulder *et al.* (1999) find that pre-existing taxes raise the social costs of an emissions tax, a performance standard and a technology mandate for reducing NO_X in the US by a factor of about 27 per cent over the cost of these policies in a model absent pre-existing taxes.

2.4.3 Graphical framework

Figure 1 provides a graphical representation of the main ideas noted above. Climate mitigation policy operates through an economic and institutional system within a country that leads to reductions in GHGs, changes in other pollutants, and mitigation costs. The emission changes work through an ecological or environmental system that eventually feeds back into the economic system. Then, depending on conditions of the economic system and its institutions, such as labor markets, tax systems, existing environmental and other types of regulations (represented by the box labeled "Ancillary Policies") these feedbacks may become environmental externalities (such as changes in conventional air or water pollution), non-environmental externalities (such as employment effects) and, of course, climate change externalities (such as leakage of carbon emissions). Ultimately, and from a country's efficiency perspective only, the net ancillary benefits/costs may be compared to mitigation costs. Note that there are a variety of additional interrelationships that we are omitting from this graphic. An example is that estimated health benefits might be lower if we recognize that a climate change mitigation policy could hold down temperature increases and, therefore, create less ozone than in a model not allowing for this feedback.

Figure 1. **Ancillary benefits and costs of climate change mitigation: A conceptual framework**



3. Baselines

3.1 Definition

One of the most sensitive elements in the analysis of ancillary benefits from a policy is the "counterfactual" -the assumption of what would happen in the absence of the policy, usually termed the "baseline." The feature that most singularly distinguishes the quality of previous studies of ancillary benefits is the clarity and careful articulation of the baseline, or lack thereof. Since in principle the baseline is a complete picture of one alternative future, it should be specified carefully with respect to its most important characteristics, including those we touch on here.

3.2 Consistency of baseline treatment

In considering ancillary benefit estimates in the context of how policy can use this information, a theme we return to repeatedly, it is extremely important to achieve consistency in baseline assumptions among studies that influence the policy debate, or at least to make the implications of their differences explicit.

For example, imagine an analysis of the costs of GHG policy that examines costs in Europe based on an economic model from 1990 but failed to account for changes in energy use that are expected to result from the Second Sulfur Protocol. The Protocol is likely to raise the cost of coal-fired power production and affect the relative cost of coal and other fuels. But the GHG cost analysis would assume a lower cost of coal-fired power in the baseline, and hence it would overestimate the cost of carbon reductions relative to what would obtain if the Second Sulfur Protocol were accounted for. How should an ancillary benefit analysis be framed in this context?

If the ancillary benefit analysis is enlightened with respect to the role of the Second Sulfur Protocol, it would assume lower sulfur emissions in the baseline than are implicit in the GHG cost analysis. Hence, it would conclude the ancillary benefits from changes in sulfur emissions would be relatively low. However, this would impart an important inconsistency in the two analyses and it may provide spurious information for policy-makers who presumably wish to consider total direct and ancillary benefits and costs. Taken together, the two studies would overstate the total cost of GHG policy relative to its benefits. Given the fact the GHG cost analysis erred in its assessment of the regulatory policy baseline, the consistent assumption for the ancillary analysis is the same regulatory baseline. Otherwise, the social opportunity costs and benefits of the GHG policy will be misrepresented.

The importance of the baseline issue is evident in the review of previous studies for the US in Burtraw *et al.* (1999). Though the studies that are reviewed varied for a number of methodological reasons, the most apparent was the treatment (inclusion or not) of the 1990 US Clean Air Act Amendments and especially the tradable permit program for SO_2 (see next section). This difference explained most of the difference in monetary assessment of benefits in the recent studies of ancillary benefits for the US.

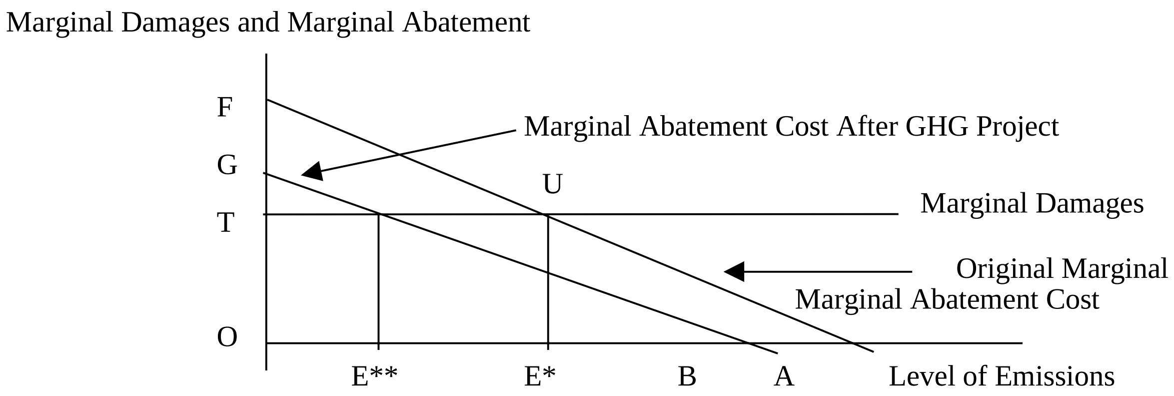
Generally, it is unclear which baseline is preferable for the ancillary benefit analysis. It may be that the opportunity costs of GHG policies is affected relatively more by regulatory changes than are the ancillary benefits, or the opposite may be the case. The preferable approach would be to replicate the baseline that is the foundation for studies to be included as a basis for policy, while perhaps also attempting to forecast regulatory changes that might seem important for ancillary benefits.

3.3 Types of baselines

3.3.1 Regulation of conventional pollutants

In Section III we noted that the relevance of external costs depended on the regulatory framework in place.[8] If the government has taken measures to internalize observable external effects such as damage from conventional air pollutants, then the ancillary effects of GHG reduction may not yield corresponding economic benefit equal to the change in the external cost. The reason is that pre-existing regulation has already incorporated into product prices some portion of external costs. In fact, the policy may create a divergence between the market price and the social cost. The point can be illustrated in Figure 2 below, where we plot marginal damages from fossil fuel emissions and the marginal costs of abatement of those emissions. We assume that the marginal damages are constant and do not vary with the level of emissions (a reasonable assumption in the light of the empirical evidence on this - see e.g. European Commission, 1999).

Figure 2. **Ancillary benefit estimation with different regulations**



Suppose that the government has a tax on the emissions of OT and the resulting emissions are set at OE*. In that case the externality is fully internalized, the government receives a revenue OT*OE and no further adjustment is required. If a GHG reduction policy is now introduced, it will reduce the marginal abatement cost for the fossil fuel from AF to BG. What are social benefits of this change? The components are as follows:

- Loss of government revenue.
- Savings in abatement costs.
- Changes in external costs.

In this case the change in the external costs is exactly balanced by the loss of government revenue (both are OT*(OE* - OE**) so the only benefit is the savings in abatement cost. More generally, the tax may not be equal to the marginal damages. In that case it can be shown that the ancillary benefits are given by the change in abatement costs plus the difference between the marginal damages and the tax rate, multiplied by the reduction in emissions (see below).

8 For applications and background see Morgenstern, 2000; Burtraw *et al.*, 1999; Lutter and Shogren 1999; Burtraw *et al.* 1996; Ekins 1996; Freeman *et al.* 1992.

Now consider the case where there are tradable permits for the conventional pollutant and the limit is set at OE*. If this limit is unchanged and if the GHG reduction is not so severe that emissions of this pollutant fall below OE*, then there is no ancillary environmental effect associated with the GHG reduction. Although there is no ancillary benefit from that source, there is likely to be a decline in the cost of abating the conventional pollutant and this yields economic savings to consumers.

Finally consider the most common case where the regulation is not in the form of a charge but a command and control regulation that enforces a particular emission rate or technology standard. Imagine the regulation sets the emission rate such that emissions are E* and the emission rate standard or technology standard is maintained them at that level. As a consequence of subsequent GHG reductions, society benefits to the value of the reduction in conventional pollutant emissions multiplied by the marginal damage, plus the savings in abatement costs.

What the above analysis illustrates is that the estimation of ancillary benefits has to take account of the regulatory framework. The above examples are not exhaustive but provide a range of possibilities. To summarize, the ancillary benefits are estimated as shown in Table 2.

Table 2. **Ancillary benefits under different regulations**

Regulatory Framework(*)	Ancillary Benefits
Emissions charges	$\Delta AC + (MD - T)\ \Delta E$
Command & Control	$\Delta AC + MD\ \Delta E$
Permits	ΔAC

(*) Assumes that regulation of conventional pollutant does not change as a result of the climate policy.
ΔAC: Change in abatement costs related to the pollutant as a result of the project.
MD: Marginal damages from the pollutant ($/ton).
T: Charge rate for emissions ($/ton).
ΔE: Change in emissions.

3.3.2 Economic and energy regulation

Energy industries are regulated in a plethora of ways, sometimes even within one country. The differences can have a large bearing on the ancillary effects of GHG policy. For example, state owned electricity companies or companies operating under cost of service regulation may not have an incentive to minimize costs. Deregulated companies, on the other hand, may have such an incentive, but they may also have the opportunity to behave strategically by withholding supply to affect market prices. All these settings have different implications for the change in conventional pollutants that would result from GHG policy. For instance, state owned enterprise may provide subsidies to certain sectors or governments may pass responsibility for GHG reduction on to privately owned industry. Deregulated or unregulated companies may have lower emissions in the baseline (Oates and Strassmann, 1984). Moreover, energy subsidies may take a variety of forms that can affect the response to GHG policy. A most important feature in policy analysis is to identify these baselines, and to identify trends such as the changes in regulation. Finally, repeating the theme mentioned previously, it is important to maintain consistency in the forecasts of changes in the regulatory baseline with other studies of the costs of GHG policy.

3.3.3 Socioeconomic and demographic baseline

Changes in socioeconomic and demographic information over time can have at least two important effects. Increases in population and income can lead to changes in demand for energy and in emissions that cause marginal abatement costs for conventional pollutants to increase. Offsetting this to some degree is the rate of technological change (Lutter, 1999). On the benefit side, changes in population and income can lead to greater willingness to pay for environmental amenities, and larger benefits from reduction in conventional pollution (Krutilla, 1968). Also, improved income and other factors can improve health, which can lower baseline mortality rates. Lower rates will lower the benefits from conventional air pollutant reductions. Therefore, it is important to forecast changes in the socioeconomic and demographic baselines in the locales where ancillary benefits are to be estimated. The analysis of transportation related ancillary benefits and costs would seem to be particularly sensitive to the socioeconomic and demographic baseline.

3.3.4 Environmental baseline

Some environmental issues exhibit thresholds or other non-linearities that imply that benefits do not move directly with reductions in ancillary pollutants. Acidification is an interesting example because damage may result only after critical load thresholds are violated. On the other hand, recovery may not occur with a reduction in conventional pollutants, until some new threshold is achieved or after a significant passage of time.

3.4 Lingering issues in setting the baseline

This review has emphasized the importance of baseline issues but it is not always possible to suggest resolution to these issues, and this should be a matter of ongoing research. One lingering concern stems from the fact that the IPCC baselines lack appropriate detail for consistent modeling of population and there is no guidance with respect to regulatory baselines. Another concern is that the set of existing and potential regulations is vast, and it is not necessarily clear *a priori* which are the most important to model carefully. In addition, assessment of the environmental baseline is very difficult (e.g., nitrogen saturation, traffic congestion). Investigators should attempt to conduct sensitivity analysis to explore the importance of regulatory baselines and others that may seem most important to the conclusions of specific studies.

Finally, we note that a fundamental characteristic of the way we propose to measure ancillary benefits treats existing regulation, or some portrait of expected future emissions, as a fixed baseline. This baseline may not reflect optimal levels of control, as we have discussed previously. In addition, this baseline may not reflect optimal control were climate and conventional pollutants controlled jointly. The decision to reduce GHG will change the opportunity cost of reducing conventional pollutants, and vice versa. Compared to our formulation of the baseline, joint optimization would lead to lower costs, and hence this approach may be preferred by some analysts. This approach also introduces the cost and/or benefit allocation problem (Austin, *et al.*, 1997). The problem is to determine what portion of cost or benefit is to be allocated to reduction of GHG and what portion to conventional pollutants. We recognize that these policies are inextricably linked over the long run. However, our focus on the near-term in considering ancillary benefits provides a justification for identifying a fixed baseline that is relevant for a timeframe over which those emissions would not be likely to change, absent a change in climate policy.

4. Estimating Ancillary Benefits

New information is more valuable when it is likely that it will change decisions, in this case decisions about climate policy. If information could be generated that would be very likely to make existing ancillary benefit estimates much larger or much smaller than we find in current studies, such information would be valuable. Thus, in this section, we employ a value of information approach to highlight, based on admittedly subjective judgements, key issues in the estimation of the benefits of environmental improvements — the raw material of ancillary benefits analyses — that, were they informed by new research results, could change the nature of the ancillary benefits debate. We use our informed speculation to address potential research findings with respect to physical effects and valuation for each of the major categories of benefits. To make the discussion manageable, we confine ourselves to a developed country context and to an air pollution context. For this and other reasons, this discussion is meant to be suggestive rather than exhaustive. We hold aside those of the issues discussed above that are specific to the ancillary benefit debate, such as the effects of the regulatory baseline and the choice of climate policy on such ancillary benefits.

We start from the observation that ancillary benefit estimates range widely as a fraction of climate change mitigation costs. Burtraw et al (1999) show that the highest estimates can be reconciled to some extent with lower ones once baseline issues are addressed. But, the reconciled estimates are still a large fraction of abatement costs and there is significant skepticism about whether such values are realistic. Thus, we take it as axiomatic that new studies confirming findings from the existing literature would serve to further legitimize the view that ancillary benefits are "large." Beyond this, we want to examine what new research might find that would make such benefits even larger or much smaller.

4.1 Mortality Benefits

Mortality benefits drive ancillary benefit estimates. They are probably the most studied endpoint and clearly contribute the largest share of benefits. Some studies of the benefits of environmental improvements have found them to be several percentage points of GNP, for instance. There is, however, considerable controversy about these values and it is possible that new information could lead to far lower estimates. The following are some of the key issues that are being discussed that could lead to lower estimates.

- Most epidemiological studies have assumed, but few have searched for, the absence of thresholds in the concentration-response functions. As the bulk of the air pollution distribution is at low concentrations (in developed countries), finding thresholds could dramatically lower estimates of lives saved.

- Incorporating results from some recent studies that show synergies and interactions between pollutants could result in increased or decreased marginal damages being associated with a particular pollutant, depending on how the interaction effects work. Such effects also draw attention to the need to attribute damage by pollutant rather carefully.

- Findings that only a few days-months of life expectancy were added from pollution reductions or that the bulk of life expectancy changes occurred in the future (e.g., the latency effects from exposure to carcinogens) would result in much lower estimates of life-years saved and benefits.

- Direct particulate emissions are a minor part of the PM_{10} inventory. Secondary particulates species-nitrates and sulfates — and road dust make up a large fraction of the anthropogenic PM_{10} concentrations. While evidence exists for the role of sulfates in mortality risks, there is very little evidence on the role of nitrates and dust. If these were found not to affect health, estimates of lives saved would fall.

- Perennial debates occur about possible confounders in regression analyses providing the concentration-response functions. Discovering that these confounders are responsible for the observed effects of pollution would lower benefit estimates.

- New information showing that the WTP for reduced mortality risks is much lower for older people and people in ill health would lower benefit estimates

What new information would lead to larger estimates?

- The key mortality studies do not apply to neonatal effects; yet a growing literature finds effects of particulates on mortality of this cohort. Acceptance of these effects as real could dramatically increase benefits.

4.2 Chronic morbidity benefits

These are benefits arising from the reduction in long-term respiratory illness and heart disease. What new information would lead to far different estimates?

- Life expectancy might be found to significantly increase indirectly through reduced disease incidence, leading to larger benefits. Double-counting these as mortality benefits might be an issue, however.

- With only a few epidemiological studies on these endpoints and two WTP studies valuing changes in chronic respiratory disease (these surveyed, using a fairly untested approach, only 300 people each), any new information could dramatically alter benefits.

4.3 Benefits to ecological resources

The most controversial area for estimating the benefits of environmental improvements is benefits to ecological services, and of these, the values held by individuals that are not tied to use of the resource — i.e., nonuse values. Currently, it is fair to assume that such benefits are listed as unquantifiable, although attempts have been made to value them using a questionnaire, or ‘contingent valuation’ approach.

What new information would lead to such values being taken seriously?

- Ecological studies would become available linking marginal pollution changes to changes in ecological resources.

- The “warm glow” hypothesis or related hypotheses questioning the credibility of nonuse value elicitation would be shown to be wrong.

- Studies would be completed that found WTP for marginal changes in ecological resources and such studies would show sensitivity to scope and meet other tests called for by the NOAA Panel (which laid down the conditions that contingent valuation studies must satisfy if they are to be regarded as credible).

4.4 Materials damage

This area is rarely included in benefit analyses. Engineering studies of damage from pollution to buildings, fabrics, monuments, etc. suggest that effects, although notable, are dominated by health effects. However, the studies do not adequately cover cultural and historic monuments and their impacts.

What new information would lead to such values being significant?

- Major database effort to collect information on the inventory of sensitive materials.

- Studies showing that normal maintenance and replacement schedules would be significantly lengthened by reducing pollution.

- Studies showing the WTP for marginally slower degradation of monuments is high.

4.5 Visibility

Only in the U.S. has this endpoint been taken seriously, although the many problems with existing WTP studies have recently led to this endpoint being dropped from the peer-reviewed Cost-Benefit Analysis of the Clean Air Act, conducted by the USEPA.

What new information would lead to such values being significant?

- Studies showing that humans perceive the kind of changes to visibility in urban area that could be expected from ancillary SO_2 reductions.

- Studies showing people in these areas are willing to pay significantly for such improved visibility.

4.6 Crops and tree farming

Some studies of the benefits of reduced ambient ozone concentrations show sizable increases in yields and social welfare.

What new information would lead to far different estimates?

- Only a few crops and trees have been studied. Studies implicating ozone (or other pollutants) in other crops could raise ancillary benefit estimates.

- The key concentration-yield relationships are engineering-based and do not take into account the joint effects on farming behavior of reduced climate effects from BAU and reduced air pollution. Studies that could do this might show that these effects work synergistically or antagonistically and, in any event, could greatly alter the engineering-based benefit estimates. (There are some general equilibrium studies of crop effects, which show that the prices of crops can alter significantly when emissions levels change. This results in a change in the distribution of benefits between consumers and producers, but not in a major change in total consumer and producer surplus).

5. Ancillary Costs (i.e., negative ancillary benefits)

For all the uncertainties associated with linking *given* changes in emissions or other externality-causing actions to health and other categories of externalities, perhaps the greatest uncertainty is the most basic: *Will climate change mitigation policies lead to net increases or decreases in emissions and other externality-causing activities?* Further, will the spatial distribution of what would otherwise be net decreases in emissions result in net ancillary costs rather than net ancillary benefits?

First, the most direct effect of, say, a carbon trading policy involving Annex I countries, would be to reduce use of carbon-intensive inputs (e.g., coal) and production of carbon-intensive outputs (e.g., electricity) through pushing up prices for these types of products. Emissions of conventional pollutants and other pollutants tied to coal and electricity would fall, generating ancillary benefits. However, one must be careful to note that reduction in conventional pollutants has some perverse consequences (Wiener, 1995). Climate models capture the regional cooling that is associated with sulfates in the atmosphere. And, reduction in ground-level ozone may lead to increased exposure to UV-B radiation, especially near the equator (Bruhl and Crutzen, 1989).

Second, reduction in output of carbon-intensive commodities also could be associated with a variety of undesirable effects. Elsewhere we have pointed to the possibility of boosting employment through GHG mitigation policies. But it is also possible that employment could fall. Moreover, though the literature is controversial, a change in employment has been associated with changes in mental health, alcoholism, suicide and spouse abuse. Similarly, a change in income has been associated with other aspects of health status (Viscusi, 1994; Perkins, 1998; Lutter and Morrall, 1994; Portney and Stavins, 1994). Consequently, the negative impacts on employment or income may have social consequences that are not captured in economic models. We acknowledge that positive impacts also may have commensurate positive social consequences. Our point is simply that consideration of employment changes is a two-edged sword. Usually this effect is left out of economic models under the assumption of full employment. So when these models are criticized for failing to capture employment changes, one must recognize that the effect could point in the direction of benefits or costs.

Third, output reduction of coal-fired electricity will lead to substitution toward low carbon substitutes, which are not necessarily low in causing externalities. One example is the substitution to nuclear power in place of coal for electricity generation, which would have attendant health and other types of risks. A switch to hydroelectric power could create many negative externalities to river ecosystems. Another example would be a switch to diesel for transportation fuel, which would have a lower carbon content than gasoline but would have greater emissions of conventional pollutants.

Fourth, reduction in the use of electricity could lead to substitution toward other unmonitored fuels that may increase externalities. A potentially important example of output substitution is in home fuel use (particularly in developing countries), where a reasonable consequence of a *global* trading scenario is for an increase in indoor air pollution associated with a switch from electricity to dirtier household energy sources such as wood or lignite. This may have tremendous significance in specific locales where indoor air pollution is a major health risk, and where delays in electrification also mean delays in attainment of literacy. However, we acknowledge that in most developing nations the institutional failures in delivering and charging for electricity services pose a larger barrier to electrification than would carbon policy. More generally though, pollution or other adverse consequences may rise if electrification slows as a result of policy-induced increases in electricity prices.

Fifth, and related to the above, may be the "sink" effect. If carbon policies encourage the use of sinks for energy use, these sinks may have significant negative externalities relative to the coal they replace. Large tree farms, for instance, may create damages to ecosystems because of their reliance on monoculture. While unambiguously better from a carbon perspective, ancillary benefits may not be positive.

Sixth, there might be an "ancillary leakage effect." Imagine a carbon tax for Annex I countries that leaves carbon use in other countries uncontrolled. Such a policy would drive a wedge between demand and supply for coal and oil in Annex I countries, with a reduction in world coal demand forcing down the coal price from the perspective of non-Annex I countries. This leads to an increase in the use of coal because of the change in relative factor prices, and it leads to an expanded export market for goods in non-Annex I countries because of their relative cost advantage. (This is offset by potential shrinkage in demand in Annex I countries, whose economies are incurring costs associated with GHG policies.) The resulting increase in coal use (and in use of other fossil fuels) in non-Annex I countries — the carbon leakage — brings with it an ancillary cost of greater air pollution and other negative externalities. Because control efficiencies of conventional pollutants are lower in developing countries than in developed countries, and, perhaps, population densities near power plants and other large users of energy may be larger in developing countries, ancillary costs may be larger than suggested by carbon leakage or fuel use changes (Wiener, 1995).

To put a bit more perspective on this issue, we consulted two published articles modeling the effect of Kyoto and various forms of carbon trading on carbon leakage and energy production and consumption (Bernstein et al, 1999; McKibben et al, 1999) and obtained new runs of an improved Bernstein et al model. (See Table 3.) McKibben et al find, under a scenario where Annex I countries meet their Kyoto commitments through autarky without carbon trading among them, that energy consumption, particularly of coal, falls dramatically in the Annex I countries. In contrast, LDCs (excluding China) increase coal consumption by 0.3%, oil consumption by 5.1%, and gas consumption by 3.4% in 2010. However, consumption of these fuels falls in China by 0.8%, 0.4% and 1.2%, respectively.[9] As for carbon leakage, Annex I base carbon is 3,644 million tonnes (excluding FSU), China is 1589 million tonnes, and LDCs are 2392 million tonnes. Changes under no trading are: -1102, -12, +79 million tonnes, respectively, for 6% carbon leakage overall.

Turning to the Bernstein et al results, the coal reductions in Annex I countries are very similar to those in McKibben, although drops in oil and gas use are different. Coal consumption falls the most in percentage terms, average around 50%. Electricity consumption falls as well — 31% in the U.S., and a far smaller amount (12-19%) in other developed countries. At the same time, because of the drop in demand for these fuels, their prices fall. This leads to a 'bounceback' effect on energy consumption in the FSU as well as in the developing world, or what we have termed the ancillary leakage effect. Coal consumption rises by 4% in the FSU and 5% in the developing would. Increases in consumption of other fuels are commensurate. Electricity demand in the FSU actually increases 13%. In the developing world, electricity consumption is flat or rises slightly. This change in the use of coal is far

9 The introduction of trading among Annex I countries does not have a large effect on these percentages in China and the LDCs, but fuel consumption falls by much less in the Annex I countries.

larger that that predicted by McKibben *et al.* China and India's use of coal increases almost 1% in this study, compared to a reduction of almost 1% in McKibben *et al.*, and oil use increases almost 4% compared to a -0.4% change predicted in the McKibben *et al.* model.

Though the McKibben *et al.* and Bernstein *et al.* results differ in important ways, they share a common finding with respect to the possibility for severe leakage out of the carbon regime. In the relatively short run, while the international regime excludes important carbon sources, this suggests the unfortunate possibility of significant ancillary costs that could result from changes in conventional pollutants in certain regions as a consequence of carbon reductions under the Kyoto Protocol.

Table 3. **Illustrations of carbon leakage in modeling exercises**

Percent Change Energy Consumption from Baseline (2010)				
	Coal	Oil	Gas	Electricity*
USA	-48.2	-18.0	-29.0	-30.7
Japan	-59.3	-7.2	-48.8	-12.1
Europe	-43.1	-1.2	-27.4	-11.3
Other OECD	-43.1	-6.4	-40.4	-19.6
Former Soviet Union	3.8	4.0	12.6	12.7
Developing Countries	4.8	3.7	4.8	-

Source: Montgomery (2000).

Percent Change Energy Consumption from Baseline (2010)				
	Coal	Oil	Gas	Electricity
Europe	-51.4	-2.9	-7.6	-4.7
North America	-65.5	-15.0	-11.9	-16.8
Japan	-60.8	-14.2	7.0	-11.4
Other OECD	-53.0	-2.9	7.7	-5.1
Former Soviet Union	3.1	4.5	2.2	3.0
Developing Countries	5.6	3.7	-0.5	1.9

Source: Detailed Results from Bernstein et al (1999).

Percent Change Energy Consumption from Baseline (2010)			
	Coal	Oil	Gas
USA	-51.9	-15.6	-12.6
Japan	-43.6	-14.2	-4.6
Australia	-55.1	-18.4	-19.4
Other OECD	-49.6	-29.5	-18.2
China	-0.8	-0.4	-1.2
LDC (All countries other than OECD and China)	0.3	5.1	3.4

Source: McKibbin et al 1999.

Finally, Lutter and Shogren (1999) point out that ancillary costs could arise from the geographical reallocation of economic activity following a carbon mitigation policy. If carbon trading were in place, for instance, some areas, relative to their carbon allocation baseline, would be net sellers, others net buyers. In extreme cases, some net buyers could actually exceed their BAU carbon and conventional pollutant levels. Such cases may be far fetched. However, less far fetched is the possibility that net carbon permit buyers are near urban areas, while net sellers are not. In this case, population exposures to ancillary pollutants could increase on net, even with constant aggregate carbon emissions.

It is interesting to note that the examples of ancillary costs given above relate to ‘macroeconomic’ policy options rather than ‘micro’ decisions, where investments to replace carbon generating technologies are being considered. Although ancillary costs could also arise in such cases, they are less likely to be as significant. This underscores the point that the kinds of ancillary costs and benefits considered depend on the policies being evaluated and a specific national and institutional context.

6. Other general issues

6.1 Issues of scale/space

We have stated above that ancillary benefit estimation is primarily a country-level matter from a policy perspective, since individual countries will decide on how to achieve their agreed commitment to carbon reductions based on an assessment of the costs and the ancillary benefits of alternative actions. A related proposition is the fact that *estimates should vary in different applications*. Indeed, a criterion for evaluating the credibility of previous studies should be the way in which they vary, depending on issues of scale and space.

The series of studies on the social cost of electricity (Lee *et al*, 1995; European Commission, 1999; Hagler Bailly Consulting, Inc. 1995), and studies such as Burtraw et al (1999), make it clear that credible estimation of benefits from reductions in pollution requires modeling at the local level. The size of benefits depends on where the emissions are in relation to “receptors,” the people, economic resources, and ecological resources susceptible to pollution exposures. And the extent and exact spatial distribution of effects is determined by physical features of the medium distributing the pollution, i.e., air, stream, groundwater flows, as well as other features of the “landscape,” such as mountains, temperature, rainfall frequency, and the like.

The importance of space in determining benefits implies that economic activity will also have to be modeled at a disaggregate, spatial level. The Burtraw et al paper is probably at the limit of the aggregation over space that preserves reasonable spatial detail for benefit estimation. In this paper, U.S. electricity supply is modeled at a multi-state level (thirteen NERC regions), and then apportioned out to specific plant locations according to historic generation rates. The emission data is then aggregated back up to the state level and married to a set of source-receptor coefficients for SO_2 and NO_x emissions converted to PM_{10} concentrations specified at a state level to estimate health effects at that level. As seen in Krupnick and Burtraw (1996), which contrasts the output of several of the social cost studies, fine details of plant specification — stack heights, exit gas temperatures, type of fuel burned (high or low sulfur coal, for instance) abatement technology in place in the baseline — can make a big difference in the estimate of benefits, along with the features of the receptors (e.g. population demography, visitation to recreational sites, use of various impacted streams by fisherman; catch rates).

This degree of disaggregation may be contrasted with that typically, and appropriately, used to model sector level responses to various policies to combat global warming. Generally the computable general equilibrium (CGE) models are specified without spatial detail. Indeed, it is almost surely too much to expect that such models be designed to incorporate this type of detail without compromising their usefulness to shed light on the costs and other economic consequences of climate change mitigation. Hence, the analysis of ancillary benefits to climate change policy invites a disaggregated or local modeling strategy to complement the aggregated large scale or CGE modeling necessary to integrate economic relationships.

6.2 Treatment of uncertainty

There is general agreement that the uncertainty surrounding the estimates of ancillary benefits and costs is at least as great relative to the value of those estimates as that associated with other mitigation costs. The process by which external costs and benefits are calculated involve a number of physical modeling steps and a valuation step. The modeling involves estimation of emissions, their dispersion and transformation, and the impacts of the pollutants. The valuation of the impacts is based on statistical techniques that also have large error bounds. Each of the steps also has some uncertainty associated with it in terms of modeling choices. And the cumulative uncertainty, which is a combination of model and statistical uncertainty, could be quite large.

The first point to note is that a good study of ancillary costs and benefits will provide some idea of how large the statistical uncertainty bounds are. A single number is indicative of a misleading approach and of less than thorough analysis. The second point is that there is more than one way to report the uncertainty. For the statistical uncertainties, it is possible to derive probability intervals, using Monte Carlo methods, or by other statistical methods. For model uncertainty other methods such as bounding analysis, breakeven analysis or meta analyses have been used. Finally a method that integrates both types of uncertainty based on subjective and objective error estimates is that of Rabl and Spadaro (1998). This method provides a quantification of the uncertainty and, recognizing that many studies do not have enough information to carry out a quantitative analysis, reports a subjective qualitative indicator of uncertainty. For climate change work, Moss and Schneider (1998) suggest that model uncertainty be described as follows:

- "Well Established": models incorporate known processes; observations consistent with the models; multiple lines of evidence support the cost assessment.

- "Well posed debate": different model representations account for different aspects of observation/evidence, or incorporate different aspects of key processes, leading to different answers. Large bodies of evidence support a number of competing explanations.

- "Fair": models incorporate most known processes, although some parameterisations may not be tested representations; observations are somewhat inconsistent nut are incomplete. Current empirical estimates are well founded, but the possibility of changes in governing processes is considerable. Possibly only a few lines of evidence support the evaluations.

- "Speculative": conceptually plausible ideas that have not received much attention in the literature or that are laced with difficult to reduce uncertainties.

At the least, ancillary benefit studies should provide similar qualitative information.

7. Developing country issues[10]

7.1 Definition

Developing Countries (DC's) cover a wide variety of countries with distinct differences in terms of the economic, political, social and technological levels. The group of countries termed "Least Developing Countries" have very little basic infrastructure, the "Newly Industrialized Countries", have a structure closer to that of the industrialized countries, and others lie between these two extremes.

Since GHG limitation does not have as high a priority relative to other goals, such as poverty reduction, employment, etc. as it does in the wealthier countries the issues of ancillary benefit estimation are all the more important. Indeed, one can argue that the major focus of policy will be development, poverty alleviation etc. and that GHG limitation will be an *addendum* to a program designed to meet those needs. Taking account of the GHG component may change the detailed design of a policy or program, rather than being the main issue that determines the policy.[11]

Developing countries in general exhibit a number of specific complexities that raise further difficulties or that need even more attention than in developed countries when estimating ancillary costs/benefits. Data are limited, exchange processes are constrained, markets incomplete, and a number of broader social development concerns need to be taken into account, such as living conditions of the poor, gender issues, and institutional capacity needs. Some of these difficulties arise particularly in relation to land use sectors, but can also be important to consider in relation to the energy sector and transportation. Because of these problems, a simplified application of methodologies in developing countries can lead to a number of inaccuracies in ancillary benefits studies. We discuss four key issues that need to be addressed in developing countries studies.

7.2 Availability of adequate local valuation studies of external effects

The estimates of external effects in developed countries are derived from spatial modeling of pollutants and their impacts and from valuation studies that elicit local WTP/WTA. In many developing countries such studies are not available, although the number and quality of studies is

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10 This draws in part on the contributions of writing team for Chapter 7 of the IPCC TAR on Cost Methods.

11 For example, Markandya and Boyd (1999) and Halsnæs and Markandya (1999) have examined a number of carbon mitigation projects in developing countries including renewable energy options (biogas, solar water heating systems, PV streetlights, and wind turbines), Demand Side Management Programs, and a number of transportation sector options. An expanded assessment that includes ancillary benefits includes specific valuation of welfare impacts of increased employment, local environmental improvements related to reduced non-GHG pollutants and income distribution weights. From these applications one can conclude that an expanded cost assessment framework has major implications on the cost effectiveness ranking of mitigation projects compared with a focus on direct costs. Big differences in cost effectiveness in particular are seen for a biogas pant in Tanzania, where social costs considered in the expanded framework go down to minus 30$ per ton CO2 reduction compared with a financial cost of plus 20$ per ton CO2. This cost difference reflects a positive welfare impact on presently unemployed low-income families and time savings due to reduced fuel wood collection. The case examples generally suggest that social costs of mitigation policies in developing countries in particular will be lower than financial costs in cases, where the policies require presently unemployed labor and are reducing the damages of local non-GHG pollutants.

improving (Krupnick, Davis and Thurston, 2000)[12]. Where there is a lack of local information on WTP, one option is to use studies from developed countries and 'adjust' the estimates for local conditions. This procedure is called benefit transfer, which is defined as "an application of monetary values from a particular valuation study to an alternative or secondary policy decision setting, often in another geographic area than the one where the original study was performed" (Navrud (1994)). The problems of such transfers are discussed in greater detail elsewhere (see Davis, Krupnick and Thurston, 2000). In some respects, damages associated with activities such as transportation may be greater in developing countries, due to the greater reliance on more polluting varieties (e.g. motor bikes), poor conditions of vehicles etc. This has to be taken into account in making any benefit transfer from studies in developed countries.

Another option is to "retreat to defensible borders." At least with respect to health effects, probably the major quantifiable ancillary impact, estimates of medical costs for acute and chronic morbidity and of the value of wages lost from premature death (the human capital approach to valuing mortality risk reductions) can be obtained. While these estimates are clearly lower bounds to the value of avoiding or reducing such effects, they will not be as controversial as WTP measures and for many decisions, may be large enough compared to cost to render better information nearly worthless.

More research is needed on estimating WTP in developing countries and comparing such estimates to benefit transfers to better assess the reliability of the latter approach.

7.3 Development projections

The establishment of long-term projections for ancillary emissions is complicated and uncertain for developing countries. These economies often are in a transition process where such emissions are expected to decrease after a certain level of development, such as in accordance with the environmental Kuznets curve. It is not possible, however, to project accurately the actual speed of this process. Modeling tools and data are also very limited or even non-existent in these countries and the only available information sources for generating such projections are often the official national development plans that only cover a 5 to 10 years time horizon.

The basic uncertainty of long-term GHG as well as ancillary emissions projections encourages one to consider the use of multiple baselines, each corresponding to a particular expectation of the future development pattern. Each development pattern may exhibit a unique emissions trajectory. A nation following development policies which emphasizes greater investments in infrastructure such as efficient rail transport, renewable energy technologies and energy efficiency improvements would exhibit a low emissions trajectory. On the other hand, a nation with substantial coal resources, scarce capital and a low level of trade can get pushed towards a development path with high emissions. In the former case, climate change mitigation would have smaller ancillary benefits than in the latter case.

The spatial distribution of the population and economic activities is very different from that of developed countries, with higher concentrations in urban areas and less suburban sprawl. This high concentration, combined with poor pollution control, result in extremely high pollution levels in such

[12] The lack of studies is a problem not only for the valuation of impacts but also for the dose response functions linking pollutants to physical impacts. Such dose-response studies are also limited. Exceptions are to be found in Cropper et al (1997) (India), Ostro et al (1994, 1997, 1998), (Chile, Indonesia Thailand).

cities and therefore a greater potential benefits from reducing emissions from point and non-point sources close to or inside the cities.

7.4 Employment

Unemployment or underemployment, especially of unskilled labor is much more of a concern in developing countries than in developed ones. The best way to include employment factors is to apply a shadow price to labor, which reduces the economic cost of employing workers below the financial cost. The actual value for the shadow price depends on the opportunity cost of the worker's time, taxes, and unemployment payments etc. Details of how the shadow price can be calculated for a climate change mitigation project are given in Markandya (1998). Some illustrative examples show that using such shadow prices changes the ranking of labor intensive projects relative to capital intensive ones by a significant margin.

Shadow pricing is normally applied to the direct labor used in a mitigation program or policy. Where there are broader macroeconomic employment benefits, (e.g. through a switch of carbon taxation for taxation on employment), policy-makers generally want to be provided that information along with other indicators of benefits, such as changes in GDP, welfare 'equivalent variation' measures etc. There is little gain in trying to include the employment benefits into a single measure.

7.5 Equity

A key issue in evaluating climate change polices in developing countries is their impact on individuals differentiated by wealth, and on countries by their level of *per capita* income. For decision-making at the country level — and given that countries are sovereign, all real decision-making is at the country level-values based on local preferences, medical costs, or taken from some other local source would appear appropriate, and they should be unadjusted for income differentials vis-à-vis other countries. Climate mitigation costs are also local and should be compared with these ancillary benefits if the country is to make efficient decisions about climate change policy. A country acting in its own self-interest is free, of course, to consider equity issues in its own decision-making.

Where the *context* demands that ancillary benefits be aggregated to a global or multi-regional level, three approaches have been suggested to deal with the country-level equity issue. One is to report the income changes as supplementary information and allow policy-makers to decide on what weight to place on them. The second is to use 'income weights' so that impacts on individuals with low incomes are given greater weight than individuals with high incomes and the third is to use average damage estimates and apply them to all individuals impacted, irrespective of their actual WTP[13].

Third, it is considered unacceptable by many to impose different values for a policy that has to be international in scope and decided by the international community. In these circumstances, analysts to use the average damage value method. The analyst estimates the money value of impacts for different groups of individuals or countries and then applies the average damage to all individuals and countries. The best example of this is the value attached to changes in the risk of death. On the basis of EU/US values of statistical life and a typical value for the inequality aversion parameter Eyre *et al*

[13] The second method is in fact a special case of the use of income weights (see below).

(1998) estimate the average world value of statistical life at around one million Euros (approximately one million US dollars at 1999 exchange rates)[14].

8. Conclusions

There has been an explosion of interest in the potential for the ancillary benefits of climate change policy to offset some of the costs of reducing greenhouse gases. We define ancillary benefits to be the effects of a climate change mitigation policy other than those related directly to meeting climate change goals, that would not otherwise occur, and that are not internalized in market behavior. If the list of such effects is long and the benefits from each are large, climate policy will look like a far better deal than were these benefits not considered. Indeed, if these benefits are large enough, or concentrated enough in several places, perhaps even the shape and stringency of climate policy should be altered.

The central element of this story is that policies to abate or otherwise reduce GHGs will lead to reduced energy use, which will reduce conventional air pollutants along with it, bringing large improvements in health, visibility, crop yields, and other benefits linked to air pollutants. Additional benefits categories form a long list, including reduced traffic accidents and fatalities from lower vehicle-miles-traveled, reduced soil loss from increased tree farming, even reduced unemployment where labor is in excess supply. For developing countries that have difficulty mounting anti-pollution policy, these ancillary benefits may look like a particularly good deal if Annex I countries pay for the GHG reductions in the first place.

The purpose of this paper has been to provide a conceptual framework for evaluating this position. We considered ancillary benefits in the context of standard welfare economic theory, examined various types of claimed ancillary benefits to determine the conditions under which these claims are valid, identified factors that could lead to both far lower and far higher ancillary benefits than have been claimed, examined the possibilities that economic behavior would bring ancillary costs rather than benefits, and paid special attention to these issues in a developing country context.

The results of our investigation generally work to constrain claims of very large ancillary benefits, although some of our results point to possibilities of far larger ancillary benefits and others are neutral, in the sense that they show how sensitive ancillary benefit estimates are to economic and policy conditions. To summarize the framework we begin to develop, we consider our findings in what we believe is the most important order for analysts to consider and include in studies, and for policy makers to use as criteria in evaluating the quality of ancillary benefit studies.

1. The estimation of ancillary benefits requires localized models of environmental impacts, population, exposure, preferences and valuation. The result is expected to be estimates that vary significantly by nation or region. Indeed, *methods should be consistent and estimates should not.* Furthermore, the estimation of ancillary benefits avoids many of the most vexing problems in economics and philosophy that characterize other aspects of climate change analysis. While in general, climate change problems transcend regions and generations, ancillary benefits largely accrue in the present and in a institutional context that is largely commensurate with policy making (the national level).

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[14] The use of average values for damages implies income weights based an elasticity of social marginal utility of income (ε) of one. See also Fankhauser et al (1997).

2. We find that economic behavior in response to climate policy-induced market signals can lead to ancillary costs. Input substitution in production, substitution to unmonitored fuels, movement of energy production and consumption to countries lying outside the climate policy regime (the ancillary leakage effect), and greater reliance on carbon sinks with their attendant environmental costs all can act to create ancillary costs. It is not possible to gauge how large these costs could be and whether they could fully offset ancillary benefits. The costs of a greater reliance on nuclear or hydroelectric power, diesel fuel for transportation, and the leakage of carbon emissions to developing countries, total to significant potential ancillary costs. However, we think a full offset of ancillary benefits at a global or at the national level is highly unlikely.

3. The size of ancillary benefits is directly tied to the baseline against which such benefits are to be estimated. If, following the environmental Kuznets' curve, one assumes that controls on conventional pollutants will be tightened over time and structural economic changes will lead to less pollution per unit output over time, then residual pollution or other externality-creating activities creating ancillary benefits will shrink over time. Given the extreme sensitivity of ancillary benefits to baseline assumptions, we mainly plea for transparency in assumptions between cost and ancillary benefit analyses and sensitivity analysis. In addition, if ancillary benefit estimates are to be compared directly with the costs of GHG policies, then the assumptions especially about the baseline need to be consistent in these estimates.

4. The size of some classes of ancillary benefits (the non-environmental categories) may be smaller than is commonly assumed because of the difference in the *existence* of an externality and its *relevance for policy purposes.* For example, traffic fatality reductions and workplace fatality reduction only count insofar as auto insurance does not internalize the costs to drivers and employer liability or normal labor market behavior does not internalize these costs to employers. As another example, the benefits of technological change brought about by the GHG policy could be counted if one argues convincingly that some market failure has prevented such technological change from being otherwise realized, i.e., *that it would have been realized had the market failure been absent.* In general economists are skeptical that such unexploited opportunities are pervasive. The treatment of unemployment is another example, where any transitional increases in employment may count as ancillary benefits to the extent that labor markets fail. Here again, most economists are skeptical that these effects can be large in well-functioning economies.

5. A variety of our conclusions address the sensitivity of ancillary benefits to micro-level details, particularly spatial ones, but also details of policy. Because health and other effects depend on the spatial relationships between emissions sources and receptors, even with large reductions in GHG emissions, alteration in the spatial distribution of these emissions can result in larger or smaller than proportional increases in ancillary benefits. Regarding the effects of policy details, a particularly important one is whether the conventional pollutant is already being regulated with a policy internalizing externalities. In the case of an enforced cap on the pollutant, to the extent that a climate mitigation policy would result in cost savings in meeting the cap, these savings count as ancillary benefits. Burtraw et al (1999) show that such savings could be large (up to 30%) as a fraction of climate change mitigation costs, at least for initial bits of reduction in carbon emissions, for the electricity industry in the U.S., which is subject to an SO_2 cap.

6. Our discussions about the value of better information for conventional environment externalities point out how certain research advances may lead to larger ancillary benefits than are commonly estimated (mainly because so many potential external effects remain unquantified and unmonetized) and some may lead to smaller estimates. In the former category are the quantification and monetization of materials damages and marginal changes in ecosystem quality.

In the latter category would be findings that would lower the mortality and chronic morbidity risks of air pollution and the preferences for reduced risks of these health endpoints.

7. Particular to developing countries, we find that the transfer of values from developed countries to developing countries to monetize ancillary effects is a problematic practice. The decisions to participate in climate policy are local to the country — meaning that both local costs and local ancillary benefits should be compared (abstracting for the moment about regional effects). Therefore, indigenous estimates of value are needed to properly assess whether the consideration of ancillary benefits should alter a country's climate policy positions or activities. Benefit transfers are clearly a far second-best approach to obtaining such values. In the absence of WTP estimates, it may be useful to "retreat to defensible border" by relying on estimates of benefits that provide a firm lower bound on the full measure.

8. In developing countries issues of employment and equity also play a bigger part than in developed countries. Projects and programs must be judged in this broader framework, giving due weight to these concerns. The tools for analyzing them have been discussed in this paper. They include measures to convert employment and equity effects into monetary units, so that they can be compared with other ancillary costs. But in many cases policy makers will simply want to know, in some detail, what these effects are.

9. Our results suggest that CGE modeling of climate change mitigation costs and changing patterns of energy consumption will need to be complemented by local scale models for estimating ancillary benefits and costs, perhaps in more of a case study approach, since such modeling on a global scale will be prohibitive.

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APPENDIX: DEFINITIONS

One of the key issues is to ensure that the estimation of ancillary benefits and costs is done in a consistent manner and in the same conceptual framework as other costs and benefits. This section provides the definitions of some of the main terms that are used in the literature. An appendix provides some guidance on the basic issues that arise in the estimation of these benefits and costs.

Opportunity Costs, WTP/WTA

The key concepts in the assessment of all benefits and costs are **social costs, private costs and externalities.** Underlying these are the notions of **opportunity cost, and willingness to pay/willingness** to accept. This section provides a non-technical review of these concepts, and a discussion of how their relevance to the ancillary cost/benefit debate.

The conceptual foundation of all cost estimation is the value of the scarce resources to **individuals.** Thus values are based on individual preferences, and the total value of any resource is the sum of the values of the different individuals involved in the use of the resource. This distinguishes this system of values from one based on 'expert' preferences, or on the preferences of political leaders. These values are measured in terms of the **willingness to pay (WTP) by individuals to receive the resource or by the willingness of individuals to accept payment (WTA) to part with the resource**. The costs of WTP and WTA therefore play a critical part in the whole cost methodology. A frequent criticism of this basis of costing is that it is inequitable, as they give greater weight to the 'well off'. While acknowledging the validity of this criticism it is important to note that there is no coherent and consistent method of valuation that can replace the existing one in its entirety. Where there is a concern about equity that should be addressed separately from that of cost estimation. The estimated costs are only one piece of information in the decision-making process for climate change.

In parallel with this, a second foundation of all valuation is the notion of **opportunity cost**. The opportunity cost of providing a commodity or service (call it X) is defined in terms of the value of the scarce resources that have been used in producing X. Those in turn are measured in terms of the value of the next best thing, which could have been produced with the same resources. This notion of cost may differ greatly from the common notion of cost. For example, take the cost of sequestering carbon by growing trees on a tract of public land. In estimating the costs of such a program, what do we take as the cost of the land? In some cases a zero 'cost' is attached, because the land is not rented out and no money actually flows from the project implementor to the owner. This, however, is incorrect in terms of opportunity cost. The cost of the land is to be measured in terms of the value of the output that would have been received from that land had it not been used for forestry. Such output may be a market good or service (e.g. agricultural output), and/or a non-market good or service (e.g. recreational use)[15].

[15] In some cases recreation benefits may be marketed. Other examples of non-marketed services include soil erosion control and biodiversity conservation.

The two concepts of WTP/WTA and opportunity cost come together because opportunity cost is measured in terms of WTP/WTA. To make the example concrete, consider the example of hiring one day of labor by a construction company as part of the program of building a dyke. The WTA payment for that day of work will be equal to the value the worker attaches to the best alternative use of the time, which is the opportunity cost of that time to the worker. As for as the payment offered by the employer, the WTP will be no greater than the value of the alternative use to which the payment could be put. Hence both the WTA and WTP concepts are related to the concept of opportunity cost[16].

Social Costs and Benefits

In calculating the opportunity cost of producing a good or a service we must take account of the full opportunity cost, measured as the value of the best alternative use to which the all resources employed in producing the good or service could be put. Each of these alternative use values is in turn measured in terms of the WTP/WTA of the individuals who own the resources affected by the production process. If all the resources are accounted for in this way we have a cost that can be defined as the **social cost.**

Such a social cost may not be equal to the financial cost of a commodity or service. The financial cost of supplying electricity generated from a coal-fired power station will include payments to labor, capital and raw materials. This will not equal the social cost, however, if (a) the payments are not based on the opportunity costs of the labour, capital etc. and (b) resources such as clean air have been used up in the production of the electricity and payment is not made to those affected by the loss of that resource, based on its opportunity cost. The financial cost can also be referred to as the **private cost** of supplying the electricity if all resources under the control of the supplier are paid for in financial terms. If some resources (e.g. own labor) are not so paid for, the financial cost may differ from the private cost.

One of the most important reasons why the financial or private cost may differ from the social cost is the presence of **external effects or externalities.** Externalities are said to arise when the production or consumption of something has an impact on the welfare of someone, and that welfare effect has not been fully taken into account by the persons responsible for the production or consumption decision. In the above example, the welfare costs of air pollution from the generation of the electricity may not be taken into account by the suppliers of electricity. To fully take account of this welfare effect, the persons affected by the loss of air quality would have to agree to the loss based on their WTA payment.

The key points of note with regard to opportunity cost therefore are the following:

- The opportunity cost of a commodity is measured in terms of the value of the best alternative use to which resources used in making the commodity could be put. That is turn is given by the WTP/WTA for releasing the resource for its present use by the individuals who own the resources.

[16] In a competitive market the WTA and WTP values are equal for the last worker hired. Where the WTA and WTP values differ, we need to choose between them. This issue is discussed further below.

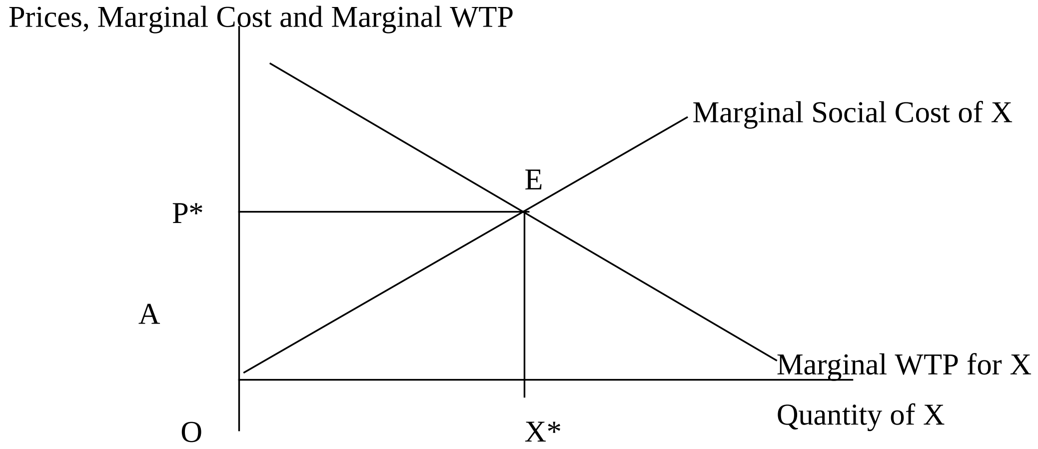
- The social cost of producing a good or service is given by the opportunity cost of all the resources that go into producing it. Some of these may not involve financial payments. Hence the financial cost may not be equal to the social cost. The financial cost is equal to the private cost if all resources provided by the party responsible for the good or service are paid for in money.

- The financial cost or private can differ from the social cost for number of reasons. The most important of these is the presence of external effects. These arise when the welfare of individuals is affected by the production and/or consumption of something but full account is not taken of that effect.

Market Prices, Marginal Private Costs, Marginal Social Costs and Externalities

In well functioning markets, where prices are determined by trades between many buyers and sellers, and where prices exist for all scarce resources, these prices are equal to the **marginal** social costs. By this we mean that the price gives the social cost of producing the last unit of the good or service. Figure A-1 below shows how the prices are determined and related to the marginal social cost and price.

Figure A-1. **Marginal social cost, marginal WTP and price**



In competitive markets producers supply goods to the point at which the price is equal to the marginal cost of production. If the latter includes all elements of cost it is called the marginal social cost curve and the market price is determined at the point at which the marginal social cost is equal to the demand for the good. The demand is in fact the marginal willingness to pay for the good or what the consumers are willing to pay for one more unit of X. Hence the equilibrium price P* and quantity X* are at a point where:

Marginal Social Cost of X = Marginal Willingness to Pay for X = P*

Note also that the marginal social cost, by definition is also equal to the sum of the opportunity costs of the inputs used in producing the last unit of X. The total social cost of production is given by the area under the marginal cost curve, or OAEX*.

In practice markers do not work as efficiently as Figure A-1 would suggest. In particular, it is important to allow for (a) the presence of externalities and (b) the possibility that private costs do not reflect opportunity costs because of other market and government failures.

Externalities, private cost and social cost

Externalities also result in a deviation between marginal private costs and marginal social costs. In Figure A-2, a negative externality will imply that the marginal private cost is less than the social cost. With the lower private cost curve, suppliers will provide an amount of X at the point where the marginal private cost curve cuts the demand curve (X**). At this point the amount of X is greater than the socially desirable level. The difference between the marginal social cost and the marginal private cost is the marginal external cost. At output X** this is given by the distance GF.

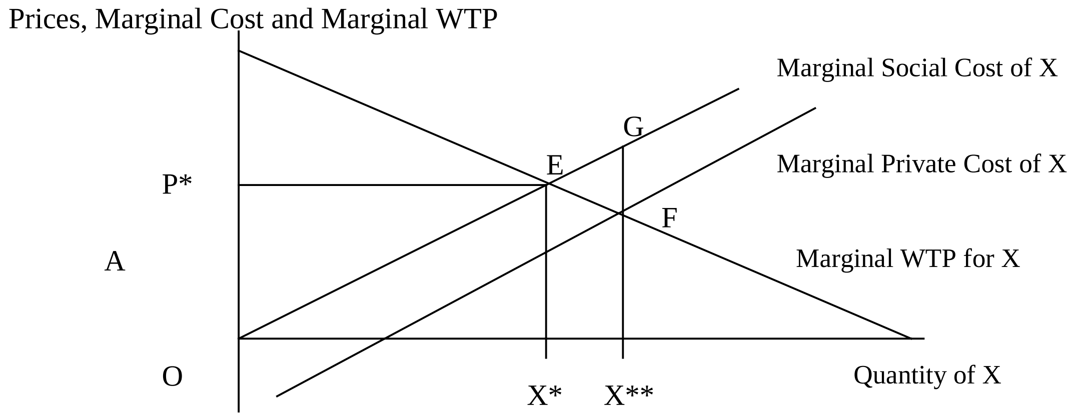
We should note that X* is 'socially optimal' and X** is not. The reason is that the social cost of producing at X** is OAGX**, an increase over that of producing X* of X*EGX**. The consumers who receive the additional production of X**- X* value it at the area under the marginal willingness to pay curve, i.e. at X*EFX**. Hence in moving from X** to X* there is a net gain, the difference between the savings in social cost less the loss of the value to the consumers. In Figure A-2 this is equal to X*EGX** - X*EFX**, or EGF. It can be shown that any point other than X* will generate some net gain when a move back to X* is considered.

What are externalities and why do they arise?

Externalities arise when there are incomplete markets. If the production of X requires a resource for which there is no market, the producer of X will use that resource without taking account of the opportunity cost of the affected party, or equivalently of that party's WTA payment for the amount of the resource that is used. Hence the marginal cost of supply does not equal the marginal social cost[17]. Such incomplete markets can arise for several reasons. One is insufficiently defined property rights. Another is the indivisibility of the resource; for example clean air cannot be 'owned' by a single person. Even if the 'right' to clean air is vested with the residents of a locality they cannot individually sell off their rights. An extension of this indivisibility occurs when the resource is a global one, such as the stratospheric ozone layer.

[17] In some cases suppliers may in fact behave as if they were facing the marginal social cost curve, if bargaining between producers and affected parties is possible. This is the famous Coase (1960) result but it is unlikely that such bargaining can take place in the context of most of the ancillary benefits of interest here.

Figure A-2. **Externalities, Marginal Social Cost, Marginal WTP and Price**



Examples of externalities that are relevant to the ancillary benefit debate include the following:

- Changes in pollutant emissions from the burning of fossil fuels.
- Increase in the availability of forested areas for recreational use as a result of reforestation.
- Reductions in public property losses from fires when lighting and heating by kerosene is replaced by electricity.

Measuring Externalities

The analysis in Figure A-2 assumes that the externalities can be measured in money terms, using values based on opportunity costs. The process of obtaining money values requires interdisciplinary work, with scientists and engineers providing data on the physical impacts and economists valuing these impacts. An example is given by the 'impact pathway approach', for air pollutants, where emissions of pollutants are measured and their dispersion and chemical interactions modeled, to provide information on the spatial distribution of concentrations. The concentrations are used to estimate the physical impacts - on health, materials, crops, ecosystems etc. Finally values are attached to the impacts, based on WTP/WTA, and models of human response to the impacts. Examples of such analysis are to be found in Lee (1995), ExternE (1999). As those studies show, however, monetization is not always possible and certainly not for all impacts. Some physical effects, particularly on water bodies and natural and semi-natural ecosystems, can only be reported in physical terms. In such cases the characterization of the externality has, necessarily, to be partly in money terms and partly in physical terms.

Issues in the definition and estimation of externalities

There are a number of complications that arise in applying the theory of externalities, which anyone working in the field has to be aware of. These are:

- The distinction between market externalities and pecuniary externalities.

- The importance of the regulatory framework in assessing the policy relevance of measured externalities.

- The need to be consistent in the accounting framework.

The distinction between 'real' externalities and pecuniary externalities

The externalities described above are 'real' in that they result from a lack of markets and are relevant in comparing private and social costs. The literature also refers to pecuniary externalities, or changes in incomes resulting from a GHG mitigation project. Such changes can be thought of as 'externalities' in the sense that the impact on the person or firm is unexpected and/or unintended. But they are not to be confused with the market externalities. The following examples should help clarify the picture.

A carbon sink project creates an improvement in a local amenity by reforestation. The market externality is measured in terms of the WTP of the individuals who would use the amenity. This use could, however, also generate an increase in the fees received by the park owners, and increased profits by facilities in the region that provide services - restaurants, hotels etc. The latter are all pecuniary externalities and including them in the assessment would amount to double counting.

A GHG mitigation transport project reduces air pollution by switching from private to public transport. One of the impacts of this switch is the increase in income for the providers of public transport and the fall in income for car maintenance services, car sales outlets etc. These changes operate though organized markets and are not relevant to the estimation of the external effects of the reduction in air pollution.

The importance of the regulatory framework in assessing the policy relevance of measured externalities

When external effects are present, governments may take actions to mitigate them. These actions may reduce the gap between the 'socially optimal' level of the good and the amount that the private sector would supply. In terms of Figure A-2, for example, a tax on the private supplier equal to FG per unit of X would result in the private suppler having a marginal private cost curve that results in an output decision of X*. In that event an externality is still present, but it is no longer 'relevant', in the sense that no further adjustments to output need to be made on account of the externality.

This is an important point because it underscores the distinction between the **existence** of a measured externality using methods such as those described above, and the **relevance** of the externality for policy purposes. The latter requires much more information - especially about the role of the regulations in bringing the social and private decisions closer together. The issue arises in the context of ancillary benefit estimation and is discussed further in Section IV.

The need to be consistent in the accounting framework

There are some areas where the theory of externalities applies less clearly than others. The above examples of 'real' externalities are ones where hardly anyone would doubt the relevance of the theory. But there are also some less clear-cut cases. One is the in the change in efficiency in the use of technology brought about by GHG mitigation measures. The problem here is the definition of the 'market', which is missing and the fact that the efficiency gains occur to individuals who should be able to take account of such gains in their decision-making. The case for treating such gains as external is that individuals may not be aware of the possible gain and therefore the 'missing market' is that for information on the effects of adopting different technologies on future costs of those technologies. What is decided as to the externality status of this impact is, therefore, a matter of debate. **If**, however, we treat technological efficiency as an externality, it is critical that the opportunity costs of obtaining the improvements in technology, including R&D elements are included as cost items.

A second example of an 'externality' where there is some doubt is with respect to reductions in fatalities from road accidents when there is a shift from private to public transport, or the reductions in death rates from reductions in air pollution. In both cases individuals acting rationally should be aware of such impacts and, in principle, the property rights for safety and clean indoor air are well defined. The issue, as in the case of technology efficiency is information. If individuals are not aware of the risks, or are not able to exercise a choice with respect to the risk level they would like because of market imperfections, there is case for including them as externalities. In that event, however, it is important to include all costs associated with the change in behavior resulting from the programme or policy that reduces these risks.

Other government and market failures

The discussion so far has been about externalities, or situations where missing markets cause a divergence between private and social costs. Such divergences can also arise, however, for other reasons. Prominent among them are:

- Government subsidies and taxes.
- Government controls that restrict, in one form or another, the supply for demand for a particular input or output.
- Market imperfections such as monopoly or monopsony power.

All these factors result in market prices deviating from marginal social costs. Hence in making a proper assessment of the social cost this divergence has to be allowed for. The following are some important examples of divergences and how they may be addressed.

Labor and capital market imperfections

Adjustments to for deviations between private costs and opportunity costs in labour and capital markets are made through the use of 'shadow prices'. As an example, if the wage paid to a worker is \$30/day and the opportunity cost of his or her time is only \$15 a day, a shadow price of 0.5 is applied to the actual wage to get the social cost of that input. The underlying imperfection in this case may be union power which keeps the wage artificially high, or macroeconomic failure, which prevents the labour market from clearing. Likewise, where capital markets are distorted, the market price of capital may not reflect its true scarcity. This would imply the need to apply a shadow price to capital of greater than one; something which is routinely done in project appraisal by public sector investors. The details of how such premia can be calculated are discussed in standard treatments of the subject (see, for example, Ray (1984)).

Shadow Prices for Goods and Services

The standard assumption for social cost pricing of all goods and services is to take the international prices[18] for all tradable commodities. This assumes that international prices are indeed free market prices. If that is not the case, an adjustment must be made to the international price to reflect any divergence from social cost. Note that such adjustments will mean that all inputs and outputs will be valued net of any taxes or subsidies.

The discount rate

The debate on discount rates is a long-standing one. As the SAR report notes, there are two approaches to discounting; an ethical approach based on what rates of discount **should** be applied, and a **descriptive** approach based on what rates of discount people (savers as well as investors) actually apply in their day-to-day decisions. The former leads to relatively low rates of discount (around 2-3% in real terms) and the latter to relatively higher rates (at least 5-6% and, in some cases, very much higher rates).

Although there is a good case for using low discount rates to evaluate climate change impacts (see, for example, the discussion in the SAR), the same does not apply to mitigation programs and polices. For these, the country must base its decisions at least partly on discount rates that reflect the opportunity cost of capital. In developed countries the rates are around 4-6% would probably be justified. Rates of this level are in fact used for the appraisal of public sector projects in the EU) (Watts, 1999). In developing countries the rate could be as high as 10-12%. The international development banks use these rates, for example in appraising investment projects in developing countries. It is more of a challenge, therefore, to argue that climate change mitigation projects should face different rates, unless the mitigation project is of very long duration.

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[18] The relevant prices are the international price f.o.b. from the country concerned for goods that are exports or potential exports, and c.i.f. to the country for goods that are imports or import substitutes. Where goods are not tradable, shadow prices are estimated using the costs of production with inputs priced at international prices.

In addition to discounting future costs and benefits of climate change and mitigation programs, there is the further issue of whether or not future emission reductions should be discounted when compared to present reductions. The justification for discounting them is that future reductions are worth less than present reductions in terms of reduced impacts. The choice of the appropriate rate, however, remains an unresolved issue. A recent survey of discount rates applied to carbon flows reveals values ranging from 0 to 10 % (Boscolo, Vincent and Panayotou, 1998). Some studies do not apply a discount rate but simply take the average amount of carbon stored over the project life-time (referred to as flow summation) or take the amount of carbon stored per year (flow summation divided by the number of years). Both these methods are inferior to applying a discount rate to allow for the greater benefit of present sequestration over future sequestration. The actual value, however, remains a matter of disagreement, but the case for anything more than a very low rate is hard to make.