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ACTING GLOBALLY WHILE THINKING LOCALLY: IS THE GLOBAL ENVIRONMENT PROTECTED BY TRANSPORT EMISSION CONTROL PROGRAMS?

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Locally motivated air quality programs in Santiago and Mexico City have only minor collateral benefits for the global climate. If agencies with global and local agendas did business together, then individuals and firms and even cities would act globally when thinking locally, and one would see greater synergy. Eskeland and Xie find that locally motivated air quality programs for urban transport have limited collateral benefits in terms of protecting the global climate. This could puzzle some, since these two public goods one global, one local seem to be jointly produced. However, air quality in Mexico City, Santiago, and elsewhere is predominantly pursued by technical improvements (making cars and fuels cleaner), and not by reducing demand for polluting goods and services (though in Europe high fuel taxes help reduce demand). Control programs developed under joint stimulus to protect the global and local environment have not yet been seen, and they may surprise us when they come. However, they will likely rely more on reducing demand, using instruments such as corrective (Pigovian) taxes on fuels. The authors show how, if locally and globally charged agencies can do business together, consumers, producers, and cities will act globally when thinking locally. Only then will we know the extent to which local and global benefits are produced jointly.

I. Introduction: A Local Public Good and a Global Public Good

Local air pollution tends to be awarded priority over global climate change concerns, due to the adverse effects on health resulting from local pollutant emissions. Such health damages have long been recognized in the

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industrialized world, and polluted cities in industrialized countries—such as in the Ruhr area of Germany, in London, and in Pittsburgh—have long ago moved to control dust emissions.[1] Even now, as particle and lead concentrations have been reduced in many cities, and the main priority is reduction in ground-level ozone, expected improvements in public health are the main driving force. In many developing country cities, air quality is an emerging priority, and the main motivator is again health effects (see, for instance, World Bank 1992; Ostro 1992; Ostro et al. 1996, 1998; Working Group 1997, and Cropper et al. 1997). As examples, in Jakarta, Indonesia, an estimated 1500 premature deaths are caused annually by air pollution (Ostro 1992). A recent World Bank report (World Bank 1997) estimates that each year 178,000 Chinese suffer premature deaths because of urban air pollution. Health effects of air pollution are demonstrated in cities as diverse as Beijing, Krakow, New Delhi, Sao Paulo, and Santiago, and are expected to be important in hundreds of cities in developing as well as industrialized countries. In a study of Santiago, Chile, an air pollution control strategy was found to be fully justified merely by modestly estimated improvements in public health (Eskeland, 1997).

There is also increasing evidence that human activities (including the use of fossil fuels) cause global climate change, with a range of adverse impacts on economy and environment in many countries (see, for instance, IPPC 1996; Cline 1992). The Intergovernmental Panel on Climate Change (IPCC) concluded that "the balance of evidence suggests a discernible human influence on global climate."(Houghton et al. 1996). The IPCC also estimates that unabated emissions of greenhouse gases will lead to a rise of 1 to 3.5 degrees Centigrade in global temperature and a 15 to 95 cm rise in sea level

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[1] In "The Economics of Welfare" (1920), A.C. Pigou used activities emitting "smoke" to illustrate that social returns can differ from private returns, and cited studies giving quantitative estimates for damages from Manchester and Pittsburgh. The term "Pigovian taxes," reflects his demonstration of a coordinating role for government, and taxes on emissions as the recommended policy instrument.

by 2100. This could result in the inundation of low-lying areas, changes in cropping patterns, increased drought and flooding in some areas, and loss of biodiversity, among other effects. Changes in the frequency and intensity of tropical monsoons could increase flood deaths and other damages.

This study uses the term *public goods* for air quality and the global climate, not because the control should be by the government—the government is anyway just a conduit for private resources. Rather, the term public goods is used because enjoyment of air quality and climate is *non-exclusive*—such goods can be enjoyed by one individual without excluding the enjoyment by another. The contrast to public goods are private goods—sometimes called rivalrous—such as bread, for which each slice is had by one person *or* another. Air quality is called a local public good because its benefit domain is confined to a city, or an airshed (e.g., a valley), while the climate is thought of as a global public good for obvious reasons (the world we share is spherical). A long-standing theme in public finance, originating with Pigou (1920), is that public goods such as air quality and public safety create a need for coordination beyond what would be delivered by voluntary trades and the market mechanism. Emission taxes and regulation are amongst coordination mechanisms discussed in the literature.

The question we ask in the following study is to what extent there is synergy *in the solutions* to urban air pollution problems and global warming problems. In other words, we ask whether two public goods, one with a local domain, and one with a global domain, are jointly produced, in the same way as are mutton and wool. A number of studies have addressed this problem in different ways. For example, Burtraw and Toman (1997) review studies that assess environmental ancillary effects of greenhouse gas mitigation policies. Our approach is somewhat different, since we look at how two differently directed policy agendas would interact through their strategies and whether local and global benefits can be achieved simultaneously.

In our paper, we study some aspects of integration between local air pollution problems—the way they are experienced in metropolitan areas such as Santiago, Chile and Mexico City—and the problem of global climate change. The integration involves aspects of environmental science and engineering, of economics and of institutional mechanism design. The two problems have in common that they are caused in part by emissions from human activities, and in particular by byproducts of combustion of fossil fuels. On this basis alone, one could say that there is a strong synergy in the sense that a complete shutdown of combustion activities would likely solve much of urban air pollution problems as well as saving the global climate. In our study, however, we examine more realistic (and indeed more attractive) strategies, such as modest reductions in fuel combustion, and carefully designed urban air quality control programs. Along these lines of collective action, we will show that the "jointness" in production of the two public goods is not as obvious—not as firm—as one might expect.

The structure of the paper is as follows: In part II, we review locally motivated vehicular emission control programs for Mexico City and Santiago, and explain how the goals pursued differ from those relating to the global climate change agenda; in part III, we examine quantitatively the synergy between the two objectives, and check how local programs would be modified if credited with 'collateral' global benefits; in part IV, we show how fuel taxes can be used alone or together with other instruments to pursue both goals; and in part V we envision a scenario wherein agencies with local and global agendas do business together.

II. The Background Studies: Two Locally Motivated Emission Control Programs

While emissions from the same polluting sources contribute to both local and global problems, the type of emissions that contribute to each are very different. Thus, an urban air quality agency and a climate protection agency dislike different byproducts of combustion, in the same way as wool merchants and butchers appreciate grazing sheep for different reasons.

In this study, we use measures of six local air pollutants and three greenhouse gases (GHGs). We have explained in Annex 1 our central assumptions and sources regarding emission coefficients and how they are given priority weights according to a local and a global agenda, respectively. A few reports (see Eskeland 1994 and World Bank 1994) explain the basis for weights representing local priorities. These should not be considered “final answer”, but estimates based on present knowledge and plausible assumptions. Central to our argument here is that emission components weighted locally are not weighted globally and vice versa. This proposition is not likely in serious dispute.

Major local air pollutants emitted by motor vehicles are nitrogen oxides (NOx), volatile organic compounds (VOCs), carbon monoxide (CO), sulfur oxides (SOx), particulate matter less than 10 microns in diameter (PM10), and lead. Their relative weighting is also associated with uncertainty and professional debate. Among these the problems and priorities will—and should—differ from one city to another: Early phases of urban air pollution control will typically emphasize dust and small particles (the now mostly historical London smog, which alerted the profession to air pollution’s effect on premature mortality) and lead, but this emphasis fades as those pollutants are removed. Present programs in the US and Western Europe emphasize the precursors of ozone: volatile organic compounds and nitrogen oxides, and this emphasis also inadvertently raises the emphasis of gasoline vehicles in a control program. Effects on human health will usually be key amongst the concerns in urban air pollution control programs. Such programs will not pay any attention to carbon dioxide (CO_2), and typically not to methane and nitrous oxides either—the three most important pollutants in terms of global climate change.

In an attempt to answer how urban air pollution control programs could be modified by taking into consideration global climate change concerns, we revisit locally motivated pollution control programs for transport in Mexico City and Santiago, Chile (see World Bank 1992, 1996; Eskeland 1992, 1994, 1997). The analytical bases in the two programs differ considerably, and we shall therefore use the studies differently. The Mexico City analysis evaluates in detail a wide range of technical measures in which vehicles and fuels can be made less polluting. 26 control measures remained—to be represented on the curve—after others were excluded because they did not belong on a cost-effective expansion path (Figure 1). The measures can be grouped as follows: vehicle retrofitting, emission standards and inspection programs, fuel improvements and alternative fuels. The study used a cost-effectiveness measure developed by giving different pollutants different weights, but did not produce estimates of the benefits of urban pollution reductions. The weights were dominated by accepted health considerations, giving lead a high weight, CO a low weight, and with PM10, SOx, and NOx intermediate weights (per emitted ton). The program ranked the 26 options according to cost effectiveness, to show how emission reductions could be provided at a lowest possible cost (Figure 1, adopted from Eskeland, 1994). However, since benefits were not estimated, the study did not indicate a desirable level of emission reductions.

The Santiago study, in contrast, only analyzed three broadly defined emission control strategies (emission standards for buses, cars and trucks), and thus does not have the same amount of detail in terms of technical control alternatives. Rather, analytical resources were geared towards obtaining estimates for the benefits of pollution reductions, employing models of health effects, pollutant exposure and dispersion. The Santiago study broke new ground in terms of completing a multi-pollutant cost-benefit analysis of emission controls—including costing control alternatives, dispersion and exposure modeling, dose response estimation for health effects, and valuation of these health effects (see World Bank 1994; Eskeland 1997). Ostro (1992) had laid the groundwork for using transferred dose response functions for health effects. In the Santiago study, a subset of the dose-response functions were estimated locally, lending empirical support to the working assumptions that dose response functions can be applied for transfers from other cities with similar conditions (World Bank 1994; Ostro et al. 1996, 1998).

Figure 1. Program to Reduce Local Air Pollution Emissions in Mexico City, with and without a fuel tax

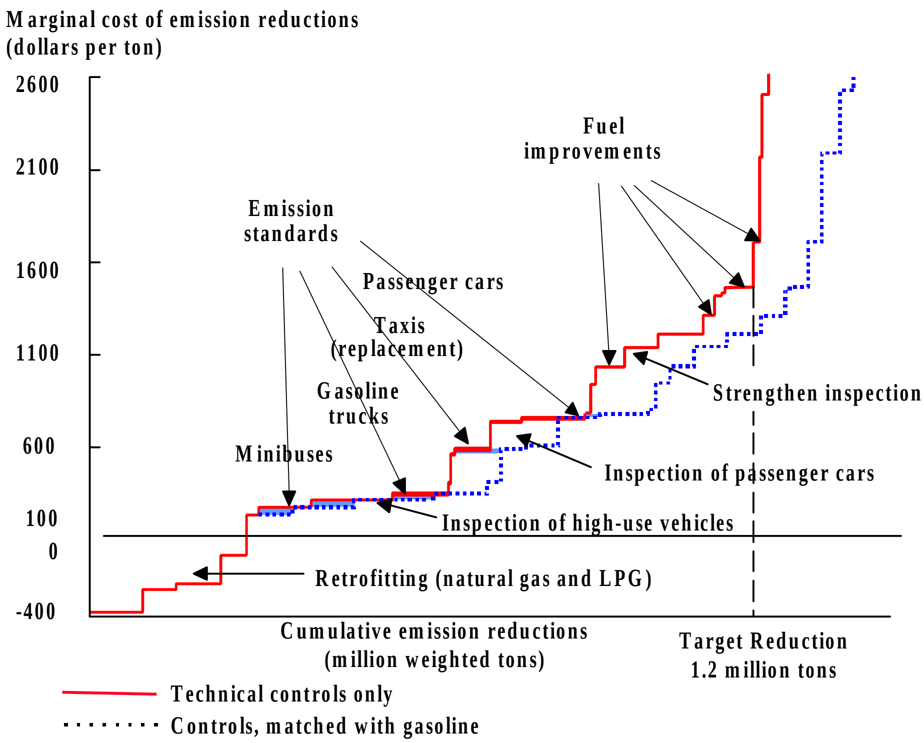


Table 1 shows health benefits, in dollars per ton of emitted pollutants, resulting from modestly estimated and modestly valued effects on human health in Santiago. To facilitate a practitioner's understanding, we have also included what this would imply in terms of dollars per liters of gasoline in the city, with alternative figures when we assume controlled and uncontrolled vehicles. However, uncertainty and discussion prevail in terms of what should be the priorities between emitted pollutants in locally motivated air pollution control programs. The approach using transferred dose-response functions for health effects has led to a high relative value on small dust particles (PM10), due to their well-documented effects on a range of morbidity symptoms as well as on premature mortality. Present professional debate gives many reasons to believe that the relative weighting of PM10 could be even higher than what is reflected in Table 1, due to downward biases both in terms of quantity and value of mortality effects. The Santiago study—in contrast to the Mexico City study, excluded effects of lead and carbon monoxide. Lead was excluded because lead in gasoline was insignificant, since it was already in the process of being phased out. Carbon monoxide was excluded because there are as yet no quantified dose-response functions in the literature. Neither of these omissions have any importance in a study of the interaction with global objectives: Lead can be ignored because lead reduction strategies operate independently of GHG emissions, carbon monoxide because carbon is valued equivalently in a GHG program whether it appears as CO or as CO_2.

Table 1. Health Benefits of Emission Controls, Santiago, Chile

	US$ per emitted ton	*Illustration: Implied Cost: US cents per liter gasoline*	
		Controlled vehicles	*Uncontrolled vehicles*
Small particles (PM10)	$18,200	0.2	0.9
Nitrogen Oxides (NOx)	$1,400	0.9	1.8
Volatile Organic Compounds (VOC)	$500	0.2	1.3
Total		**1.3**	**4.0**

Note: Four cents per liter is roughly 20 to 25 percent ad valorem, assuming a world price of gasoline of 0.8 to $1 per gallon. Source: World Bank, 1994; authors' calculations.

Prioritization of emitted pollutants as greenhouse gases (GHG) is according to their global warming potential (GWP), which puts a heavy weight on gases that play little or no role in urban air pollution control programs. Table 2 shows the relative weights for greenhouse gases used in this study, with the level illustrated by using a global benefit of US$20 per ton of carbon equivalents (i.e., $5.4 per ton of CO_2).[2]

Table 2. Global Benefits by Emitted Pollutant (according to global warming potential, GHG)

	US$ per emitted ton	*Illustration: Implied Costs: US cents per liter gasoline*	
		controlled vehicles	*uncontrolled vehicles*
Carbon Dioxide (CO_2)	$5.4	1.3	1.3
Methane (CH_4)	$134	0.0	0.01
Nitrous Oxide (N_2O)	$1,744	0.25	0.02
Total		**1.5**	**1.3**

Note: The global benefit of $20 per ton of carbon ($5.4/ton CO_2) is from Fankhauser (1995). The benefits of CH_4 and N_2O are derived by using their global warming potential factors recommended by IPCC (1995). VOC and CO are not valued directly, only in terms of their 'terminal' status as CO_2.

Comparing Tables 1 and 2, it can be seen that the pollutants (gases and small dust particles) that are valued in a locally motivated program (Table 1) are not valued in terms of GWP (Table 2), and vice versa. The hydrocarbons that are targeted for emission control in an air pollution control program, volatile organic compounds (or non-methane hydrocarbons) are targeted precisely because of their reactivity. In terms of GWP, in contrast, the only hydrocarbon that is given a value different from its terminal role as CO_2 is methane, which has a high discounted global warming potential *because* it lives long in the atmosphere in a form with much higher spontaneous global

[2] Since the global climate has not yet been given any scientifically based (or consensus) value, other values could also be contemplated (our essential points are unchanged). $20 per ton is indicated by Fankhauser (1995).

warming potential than CO_2. When emissions of VOC and carbon monoxide (CO) are reduced in a locally motivated air pollution control program, the result is merely to increase the share of carbon atoms that are emitted directly as CO_2 (more complete combustion). Such technical controls, therefore, have no significant effect on global warming. When a technical option contributes to GHG emissions reduction, it is typically because the option makes vehicles more fuel efficient. Thus, there are less pollution emissions per mile or kilometers driven, but typically not per liter of fuel consumed.[3]

III. Locally Motivated Programs and their "Collateral" Global Benefits?

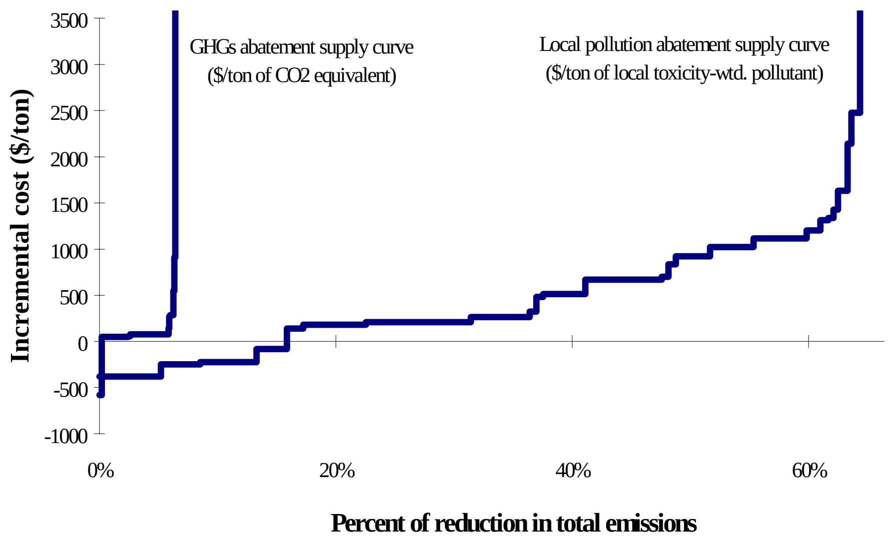
The local programs in Mexico City and Santiago are quite effective in reducing air pollution locally—the Mexico City program can reduce 64 percent of the locally weighted air pollutant emissions from motor vehicles (see Figure 1). What is the effect of local programs on GHG emission reductions? The 26 measures identified in the Mexico City study are technically oriented, and none of them deal with demand management or alternative transportation modes.[4] In part, this is why this program has a very limited effect on the global environment. Figure 2 reveals that the Mexico program would reduce only 6.5 percent of GHG emissions despite the success in local pollution reduction. In fact, the 6.5 percent may well be an upwardly biased estimate, because no changes in travel demand are assumed for these technical options, even though some of them deliver a gain in fuel efficiency. More likely, travel and transport demand would increase when higher fuel

[3] In fact, as the example showed in Table 2, the light-duty gasoline vehicle control option emits more GHGs per liter of gasoline in part because of higher N_2O emission per liter resulted from higher temperature and more complete combustion.

[4] The study (Eskeland, 1994) included arguments for and estimates of a 'matching gasoline tax', optimally to be combined with other instruments (figure 1). In Mexico at the time, gasoline prices were increased (and other taxes reduced to compensate), but whether pollution control was the dominant motivator is subject to interpretation.

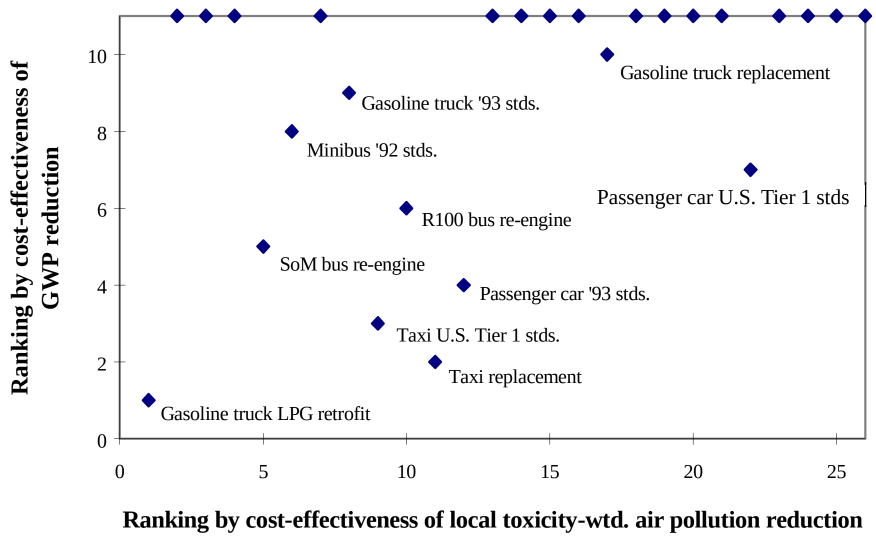
efficiency reduces short term marginal costs (Demand change and demand management will be analyzed in section 4 of this paper). This rather unimpressive synergy is found also in the case study of Santiago, Chile, for which the identified measures in the locally motivated program reduces 65 percent of local pollution from these sources but only 5.3 percent of GHGs.

Figure 2. Transport Air Pollution Abatement Supply Curves in Mexico City: Local vs. Global



Perhaps more interesting than this comparison in terms of total quantitative effects is a more detailed look at what each individual measure on the local control cost curve does to GWP emissions. One perspective is provided by reranking the 26 control measures according to GWP cost-effectiveness (Annex Table 1). In Figure 3, we have plotted the resulting cost-effectiveness ranking according to GWP against the cost-effectiveness ranking for the locally motivated program.

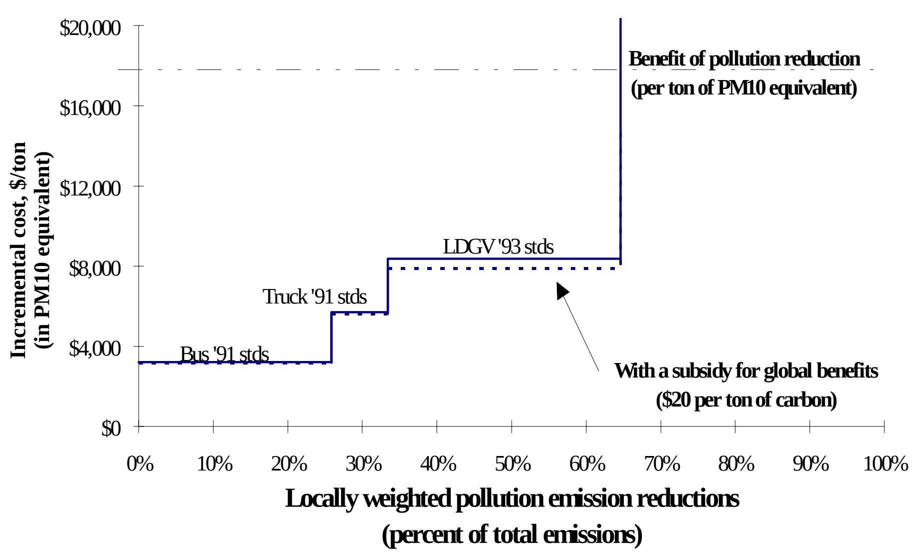
Figure 3. Ranking of Pollution Control Measures: Local vs. Global, Mexico City, Mexico



Retrofitting gasoline trucks for liquefied petroleum gas (LPG), the most cost effective measure for controlling local air pollution is also the most cost effective for climate control, but action number two and three in a locally motivated program (see Figure 1) have no effect on the climate. In general, there are two important observations to make from Figure 3. First, there is a marked lack of correlation in this figure. The technical measures that are cost effective from the perspective of controlling local air pollution are not more likely (other than accidentally) to be cost effective from the perspective of protecting the global environment (there is no tendency of a negative correlation either). Second, 16 out of the 26 identified control measures in the locally motivated program have no effect on the global climate. These are the measures that are all on the upper frame of the figure, coming in last in terms of cost effectiveness (for additional detail, see Annex Table 1, and Eskeland, 1994). Practically speaking, only strategies that make vehicles more fuel efficient or take them towards less carbon intensive fuels have an effect on the global environment (unless if they lead to less driving, see below).

In Figure 4, we examine the impact on a locally motivated program for Santiago when it is credited with 'collateral' global benefits. Figure 4 displays the control cost curve for three control options evaluated in the Chile study: emission standards for diesel buses (Bus '91 stds), standards for diesel trucks (Truck '91 stds), and standards for light-duty gasoline vehicles (LDGV '93). The upper curve includes local benefits and costs only, which was the basis for evaluation in the original Santiago study. Using the benefit weights of Table 1, all emission consequences are converted into PM10 equivalents, so as to arrive at a cost-effectiveness ranking reflecting local benefits. Given the estimated benefit of $18200 per ton of PM10, all of the three pollution control measures were attractive even when credited only with local health effects.

Figure 4. The Pollution Abatement Curve in Santiago, Chile Accounting for Global Benefits



The lower, dotted curve represents the following thought-experiment: If these three control strategies were credited with a certain value for the reductions they offer in terms of GHG emissions, how would this modify the costs? We assume a subsidy received by the policy planner from outside, but not by transport users, so no demand response is included. The figure shows that a positive value for greenhouse gases ($20 per ton of carbon and equivalents in this case) would lower the cost curve. Among these three measures, the car standards provide the higher amount of collateral GHG reductions per dollar of control costs. It therefore is the one that displays the greatest 'jointness' between the local and the global agendas. If a subsidy (or a tax on GHG emissions) for global benefits was applied at a higher rate, then climate-friendly measures (for example, the LDGV standards measure) would be more cost-effective and attractive to decision makers. Importantly, the quantitative impact of these subsidies is limited. If they were to generate a re-ranking of measures for a locally motivated policy maker, they would have to be in a radically different magnitude than $20 per ton of carbon. Furthermore, since the background study only included measures found attractive within a narrow local perspective, the study's limitations precluded that collateral global benefits could make a control measure attractive.

Generally speaking, if there is agreement on a strategy between local and global objectives in the transport sector, then it is typically because the strategy either alters total fuel consumption or because it shifts consumption towards less carbon-intensive fuels. In this case, according to the technical assumptions, the car standards improve fuel efficiency of gasoline cars (from 7.8 to 9.7 km/liter) as one of its associated effects, resulting in collateral global benefits. Under the assumption of constant travel distance, this measure will reduce GHG emissions by 40,000 tons of carbon, which means a saving of $0.8 million (being credited at $20 per ton of carbon) in total technical control costs. Notice again the assumption that there is no change in travel demand. Without complementing measures to control travel demand, this is a questionable assumption. In the following, we will take a careful look at the demand change and demand management.

IV. Demand Management: Using Fuel Taxes to Pursue both Agendas

The observed ineffectiveness of the locally motivated programs in reducing greenhouse gas emissions raises the question of whether this really is all the available synergy between local and global objectives. Before we turn to that question, we should remember that the basic idea behind environmental taxes is that they can challenge everybody—and polluters among them—to *invent* and *reveal* ways to reduce emissions. Thus, the fact that locally motivated programs do not include great improvements for the global environment could simply reflect that those programs are not developed with the global environment in mind, and thus would only by accident include global benefits. Measures to deliver local and global emission reductions have not yet—to our knowledge—received stimuli other than those conceived in desk studies such as this one. Thus, we can only speculate what control measures would come out of the woodworks if the policy environment contained stimuli for both the local and the global public good.

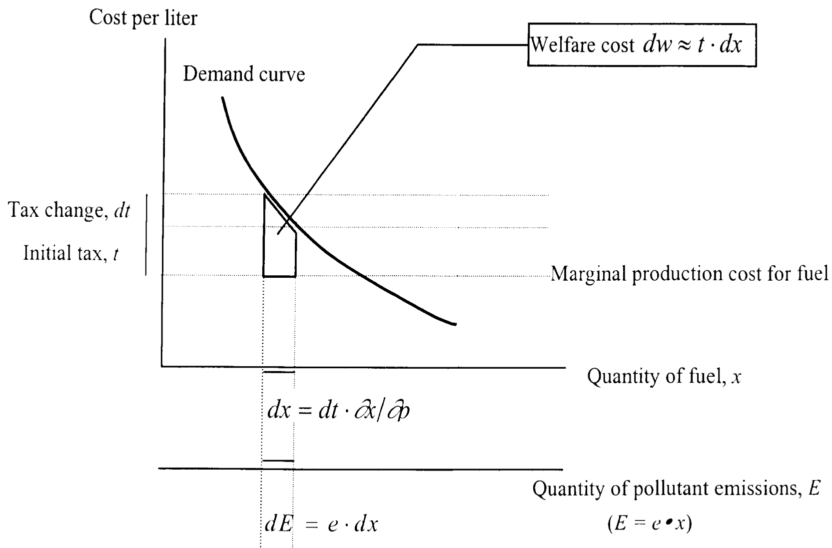
Turning to the practical task at hand, we know that a greater scope for jointness can be found when one also includes demand management in the emission control strategy. Proposals for GHG reductions often come in the form of ‘carbon taxes’, whose principal effects will be to turn users away from GHG-intensive consumption, and thus to stimulate energy conservation as well as substitution towards less GHG-intensive energy sources (from coal to petroleum products, and from petroleum products—and gas—further towards hydro- and solar energy). Box 1 explains how a simple perspective from welfare economics allows the development of a cost concept when demand is manipulated to attain emission reductions. The perspective does not include the environmental objectives in the welfare function, and thus represents costs in terms of sacrificed consumption of other, nonenvironmental goods and services. In Eskeland (1994) it is demonstrated that this cost concept is also valid when a ‘matching tax’ on polluting goods and services is used in combination with measures such as emission standards, which stimulate cars and fuels to be cleaner.[5]

Figure 5, with a locally motivated perspective (locally weighted pollutants, in PM10 equivalents, along the x-axis), displays the three control strategies of Santiago as a supply curve. The first, boldfaced curve represents the reduction in locally weighted emissions provided by the identified technical controls. Fuel consumption and travel demand are adjusted to reflect changes in fuel economy and resulting cost reduction per kilometer. This is done by assuming that the demand function for fuel is derived from demand for travel and transport. Then, an increase in fuel efficiency that is induced by regulation will result in an increase in fuel demand corresponding to the reduction in user cost for the vehicle.[6] The second curve displays the additional locally weighted emission reductions that would be obtained if one levied fuel taxes to protect the global environment, increased in a stepwise fashion. As shown in the figure, local emission reductions, then 'freeriding' on efforts to protect the global environment, would then be increased to about 71 percent, up from the 61 percent local reductions, if carbon taxes were levied at a rate of $150 per ton of carbon (equivalent to US 10 cents per liter of gasoline, or about 30 percent ad valorem). The carbon tax rate at $20 per ton ($0.013/

[5] Eskeland and Feyzioglu (1997), "Is demand for polluting goods manageable? An econometric model of car ownership and use in Mexico" aimed to see what are the costs to consumers of giving up gasoline consumption, when price instruments were used to suppress the least essential trips first. Eskeland and Feyzioglu (1997b) "Rationing can backfire: The *day without a car* program in Mexico City" analyzed a one-day driving ban used to manage demand in Mexico City. The ban was found to be counterproductive, leading to *increased* driving. This unfortunate outcome was in part because the ban does not have a self-selection property, to suppress the least essential trips first, in part because the regulation implicitly bundled cars with driving permits. Mexico City drivers responded in part by purchasing additional used cars from the rest of the country, thus not only driving more than they otherwise would have, but also with older, more polluting vehicles, and unnecessarily tying up hardware that could have been better used by others.

[6] The price elasticity for fuel is assumed to be -0.80 for Santiago, Chile, based on a conservative estimate from the study in Mexico City (Eskeland,1994; Eskeland and Feyzioglu 1997a).

Box 1. Emission Reductions with Fuel Tax Changes: Marginal Weñfare Costs



The top part of the figure is a traditional demand curve for a fuel - for example, gasoline. Under the assumption that tax revenues are as useful to society as is income to consumers (and that other taxes are zero), the welfare costs of a tax increase will be equal to the shaded area, approximated by the rectangle

$$dw \cong t \cdot dx = \cdot \partial x = t \cdot dt \cdot \partial x / \partial p$$

where $\partial x / \partial p$ is the slope of the demand curve.

The lower part is just an alternative x-axis, showing how emissions represent a constant times fuel consumption, as long as the demand changes do not change emission factors (which for fuel tax changes is a plausible approximation, if not an accurate representation). Thus, the effect on emissions of a change in the fuel tax rate is the emission factor times the demand change:

$$dE = e \cdot dx = e \cdot dt \cdot \partial x / \partial p.$$

It follows, if we divide the expression for the welfare costs by the expression for the emission reduction, that the welfare costs of emission reductions, when delivered by fuel tax changes are:

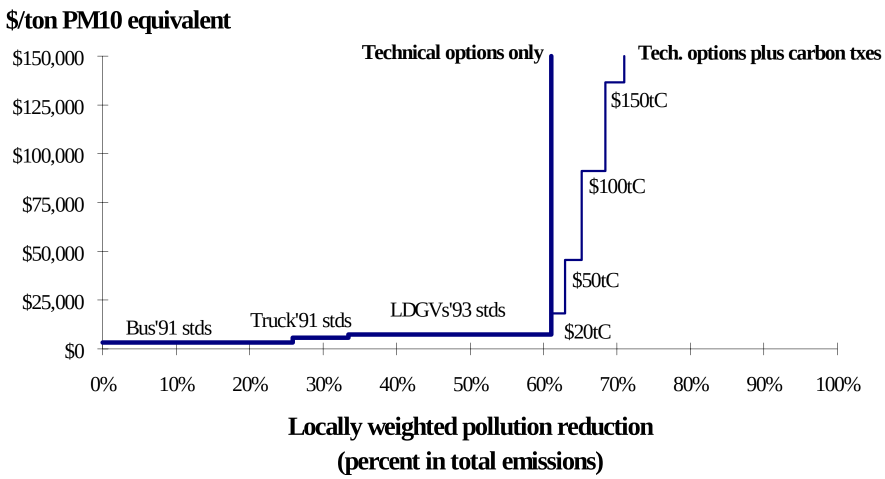
$$dw / de = t / e.$$

Thus, the part of the demand curve over the production cost for fuel appropriately can be seen as a supply curve for emission reductions (reading it from right to left). The measure of emissions, E (say, tons per year), and the corresponding emission factor e (say, grams per liter), can be chosen for the problem at hand. It could be weighted by local toxicity if urban air quality is the objective or by global warming potential if the objective is climate control, so this perspective is applicable in many ways.

liter) would expand locally weighted emission reductions from 61 to 63 percent—an important but not stunning contribution to an urban air quality program.

It is noteworthy that a fuel tax of $20 per ton of carbon is more expensive—as a means of acquiring local benefits—than any of the proposed locally motivated measures. Thus, carbon taxes that would matter for the global environment cannot be justified by saying that they would do something for the local environment: they would, but not cheaply if one does not value the global goals. This does not mean that fuel taxes should not play a part in a local program—indeed here they do—but adding a globally motivated tax does not buy local improvements cheaply.[7]

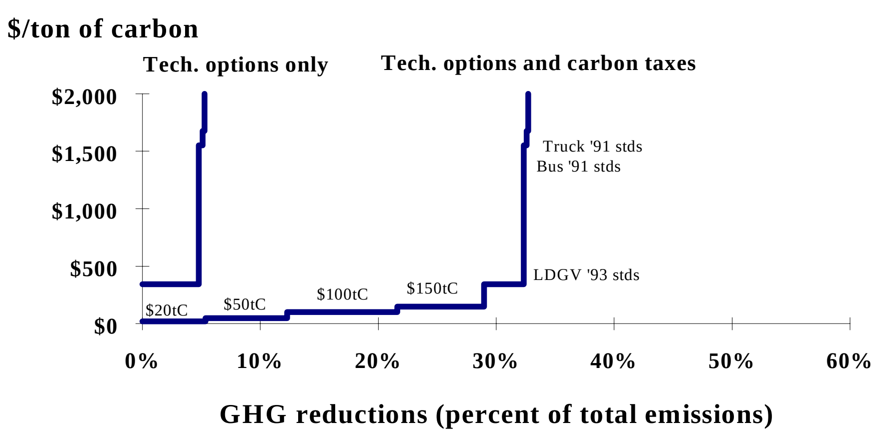
Figure 5. Local Pollution Abatement Curves: Technical vs. Tax Santiago, Chile



[7] Indeed, matching taxes on fuels are important for local programs dominated by standards. The Mexico City emission reductions come at a welfare cost 30-45% higher if the fuel tax is excluded, since more expensive technical controls must then be used (Eskeland and Feyzioglu 1997a).

In Figure 6, we have turned the table, to ask: From the perspective of a body charged with protecting the global environment, what does the pollution control program in Santiago offer? When viewed from the narrow perspective of greenhouse gas reductions, we can see that the three technical controls are costly and offer only tiny emission reductions (only 5 percent of total emissions from these vehicles at a high cost: at $340 per ton of carbon for the gasoline vehicle standard, and at $1,550 per ton of carbon for the diesel bus standard). The illustrative levels of carbon taxes offer greenhouse gas reductions much more cost-effectively. A 5 percent greenhouse gas reduction can be achieved by a fuel tax of $20 per ton of carbon. The carbon tax of $150 per ton can reduce GHG emissions by 29 percent. This figure illustrates amply how the technical controls of a locally motivated program are not well geared towards providing global climate protection and how demand management instruments such as fuel taxes will play a role in GHG reduction.

Figure 6. GHG Reduction in Santiago, Chile
Technical Options and Fuel Taxes



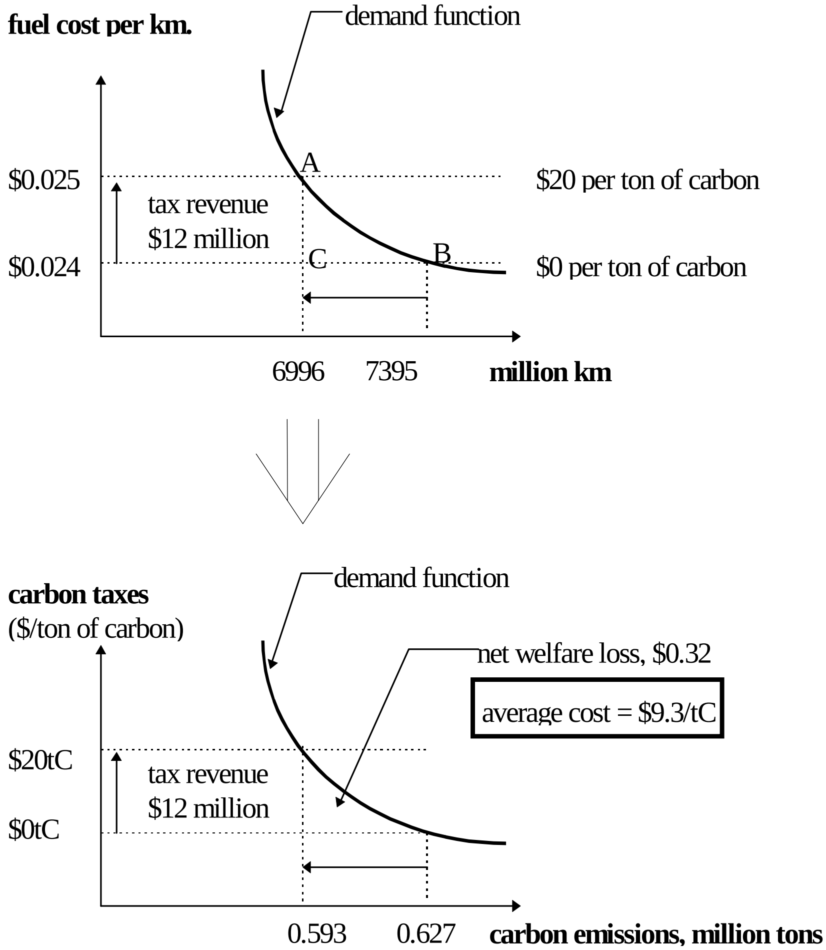
V. A Globally Motivated Agency in Business with Air Quality Agencies

As shown above, a carbon tax can be effective in reducing GHG reduction: Locally motivated urban air quality programs offer no serious competition, though they do at some point offer a sensible supplement. We also showed, however, how a carbon tax entails welfare costs locally—deterring but not killing incentives to levy such taxes.

Let us now introduce an experiment: What if an outside party—a firm, government or agency who is interested in "buying" greenhouse gas emission reductions were looking for potential providers. We could foresee such a demand for GHG reductions coming about through international treaties, including binding quotas, but also that the international agency would be authorized to purchase additional reductions from anyone. Similarly, if quota agreements are tradable, then payments will be provided between a party purchasing emission reductions from another party, not as a subsidy, but in return for services rendered.

Of course, it is up to the seller (the city of Santiago, in this hypothetical case, or perhaps the Chilean government) to determine how and whether it would offer emission reductions, and it is up to the outside buyer how much he/she is willing to pay for certain reductions or policy measures. The analysis here indicates, however, how to calculate the welfare costs to the local party (population) of delivering GHG emission reductions. We thus have an indication for the potential buyer of how much will be offered at various price levels, or what he/she will have to pay. The maximum compensation necessary would be the resulting welfare loss from the global-oriented policy. As illustrated in Figure 7, the loss is represented by the area in triangle ABC (any *incremental* loss, from additional purchases, is equal to a trapezoid like the one in Box 1: two such areas together is also a triangle). The average cost at which the international agency would be buying the emission reductions, however, would be considerably lower than the marginal costs, and exactly half the marginal cost if the demand curve is linear.

Figure 7. Gasoline taxes and carbon emissions from light-duty gasoline vehicles



In Figure 7, a tax at $20 per ton of carbon is assumed to be levied on gasoline in Santiago, Chile (similar analysis would apply to other fuels). With a simple log-linear demand function, the potential impact of the tax on the operation of light-duty gasoline vehicles, especially in terms of travel distance, fuel consumption, emission reduction, and average cost of GHG reduction, is assessed.[8] The figure indicates that a tax of $20 per ton of carbon would reduce 34,000 tons of carbon emitted from those vehicles (5.4 percent if total emissions from these vehicles) at the average cost of $9.3 per ton of carbon (about half the marginal cost, or the tax rate). The net social welfare loss (assuming no loss, or gain, from the transfer of tax revenue) is about $320,000.

Clearly, if the Chileans would do business with the globally motivated buyer at this price, the carbon tax approach is cost-effective from the perspective of GHG emission reduction. Local or national governments who adopt fuel taxes (or other similar restraints) over and beyond possible treaties and obligations can be compensated for the welfare loss, not as a subsidy but as a business transaction.

Importantly, if local governments facing such a proposal apply the same perspective, they would for local reasons apply fuel taxes representing local benefits of emission reductions, and the carbon taxes levied after the international business is completed will come on top of those. This represents no double-counting, as each agency pays for what it gets—not more, not less.

It should be noted that a framework including payment for emission reductions—as we have proposed here—rather than payment of emission taxes to the internationally charged body, involves some difficult issues of benchmarking, particularly in a long run perspective. The problem basically is that the internationally charged body should pay other parties only for measures taken over and above what they would be interested in undertaking themselves for other reasons—in other words, the incremental cost . Such problems prevail also in schemes with tradable quotas, for which the corresponding problem is associated with the initial allocation of quotas. It is a deep problem, by many found to be the cause of resistance to transferability of quotas. It does not preclude, however, that trade can take

[8] Again, we use the price elasticity for gasoline of -0.8

place on a bilateral basis, but it does require the involved bodies to be knowledgeable about their business and to be aware of what they are doing. This basically means that an internationally charged body should be aware that a polluted urban area has a self-interest in reducing local pollution, and that urban as well as rural areas should know that they have something to offer.

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Annex 1

The Greenhouse Gases (GHGs) are carbon dioxide (CO_2), methane (CH_4) and nitrous oxides (NO_2). CO_2 is harmless in terms of local pollution but a predominant source of greenhouse gases (GHGs). The contribution of CH_4 and NO_2 to global warming is often measured by their global warming potential (GWP), a ratio of the global warming effect from one kilogram of a GHG relative to that from one kilogram of CO_2 over a specified period of time. There are professional and learned disagreements about how to measure GWP (it is a question, in part, of how one discounts the effect on the greenhouse effect of the gas over time—since this effect differs for different gases) as well as the environmental costs of global warming. The GWPs used in the study are 24.5 for CH_4 and 320 for NO_2. These figures are suggested by the Intergovernmental Panel on Climate Change (IPCC, 1996) for a timeframe of 100 years. Due to lack of GHG emission information in study cities (this is a general case in most developing countries), we adopt GHG emission factors in U.S., reported by IPCC (1996). This can be justified by the facts that most vehicles operating in Mexico and Chile are mainly manufactured in U.S. and other developed countries and that pollution emission standards adopted or going to be adopted in these two countries, to certain degree, are based on U.S. emission standards. In addition, we assume that the average cost of global warming is US$20 per ton of carbon, i.e., $5.4 per ton of carbon dioxide equivalent.[9]

[9] This number is based on a study by Fankhauser (1995).

Annex Table 1: Ranking of Pollution Control Measures, Mexico City

	Ranking by	
Measure	*Toxic-wtd.*	*GWP*
LPG retrofit for gasoline trucks	1	1
Taxi replacement (Mexican '93 standards)	11	2
U.S. Tier 1 standards for taxi (incr.)	9	3
Passenger car '93 emi. standards (new veh.)	12	4
Re-engine light-diesel buses (U.S.' 91 stds.)	5	5
Re-engine R100 buses (CA'88 standards)	10	6
U.S. Tier 1 stds. for pass. cars (incr.)	22	7
Minibus '92 emissions standards	6	8
Gasoline truck '93 emissions standards	8	9
Gas. truck replacement ('93 standards)	17	10
CNG retrofit for minibuses	2	11
CNG retrofit for gasoline trucks	3	11
Gasoline vapor recovery	4	11
Central I/M for high-use vehicles	7	11
Diesel especial (0.4 percent sulfur)	13	11
Lower Nova RVP (pre-'91 pass. cars)	14	11
Nova Sin (pre-'91 pass. cars only)	15	11
Decentralized I/M for passenger cars	16	11
5 percent MTBE Nova Sin (incr., pre-'91 pass. cars)	18	11
Lower Magna Sin RVP to 7.5	19	11
Road paving (1000 km.)	20	11
0.1 percent sulfur in diesel fuel (incr.)	21	11
Diesel meeting US 1993 specs. (incr.)	23	11
11 percent MTBE Nova Sin (incr., pre-'91 pass. cars)	24	11
5 percent MTBE in Magna Sin	25	11
11 percent MTBE in Magna Sin (incr.)	26	11

Note: The measures ranked at No. 11 by GWP reduction actually have no gain in GWP reduction.