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THE EFFECTS OF CARBON TAXES ON ECONOMIC GROWTH AND STRUCTURE WILL DEVELOPING COUNTRIES JOIN A GLOBAL AGREEMENT?

by

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ABSTRACT

The prospect of global climate change resulting from accumulations of gasses in the atmosphere has generated various proposals aimed at curbing activities which produce these gasses. One of these is the imposition of a global "carbon tax" on fossil fuels designed to discourage use of energy sources which produce carbon dioxide. This paper analyzes the costs and benefits of implementing such a policy in economies with different structures and levels of development. It is argued that developing countries will bear a disproportionate share of the costs and that the transfers required to enable them to participate without significant losses in the short run are so large as to be unlikely. In addition, costs will be larger in the short run than in the long run view taken by most analyses of this issue, posing additional disincentives to participation for leaders of developing countries. The paper concludes that carbon taxes are unlikely to be adopted if their justification is the goal of reducing fuel use via the price mechanism, but may be adopted at a much lower level in order to fund research and development of new technologies.

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I. Introduction

The problem of global warming resulting from the accumulation of various gasses in the atmosphere has been a topic of considerable concern in recent years, and has generated a variety of proposals designed to help address the problem. These proposals have important ramifications for the world economy since most of the gasses which cause the problem are a direct byproduct of economic activities, most importantly the combustion of biomass and fossil fuels.

Carbon dioxide (CO_2) is the most important of the gasses contributing to the "greenhouse effect" in which accumulations in the upper atmosphere inhibit heat loss from the Earth while still allowing incoming solar radiation to pass to the surface. Figure 1 shows a recent estimate of the relative contributions of different gasses to the overall problem. While other estimates place the share of CO_2 as high as 70%, even conservative estimates like that shown here make it clear that CO_2 accounts for by far the largest share of the problem. (See Drennen & Chapman 1992) The next most important contributor, CFC's, are already subject to an international treaty and are in the process of being replaced by substitute chemicals in many applications.

Given the importance of CO_2 and the fact that the excessive accumulations are primarily a by-product of the use of carbon-based fuels, one of the most commonly cited policies which could be used to reduce emissions is a carbon tax.[1] This tax would be applied to fuels based on their carbon content and would result in prices more reflective of the true costs of burning them. Such a tax would, of course, have important economic consequences since fuel prices would have to rise considerably if substantial reductions in use are to be achieved. Several analysts have estimated that marginal tax rates on the order of 500% for coal and 100% for gasoline would be required to achieve a halving of carbon emissions. Taxes this high are nevertheless still cheaper to implement than a "command and control" regulatory approach would be, since economic incentives are more efficient than bureaucratic regulation and allocation (See Hoeller, et. al. 1990).

It is clear that a global solution is needed to this problem, not least because it affects all parts of the globe. However, it is important to realize even though not all countries contribute to the problem in the same degree, it is imperative that all countries be involved in agreements or proposals to address the problem. More concretely, Figure 2 shows the contributions of different countries to the total accumulation of

CO_2. It is obvious that developed countries and the U.S. in particular are far bigger producers of GHG's than are low income countries. This is illustrated by the range of per capita CO^2 emissions in the Western Hemisphere, where the U.S. is the leading emitter with more than 170 times the level of Haiti, the lowest.

This fact has led some to argue that those who caused the problem should shoulder the burden of solving it, while leaving poor countries out of potentially costly schemes such as a global carbon tax. This view is appealing in that it seems only just to make those who caused the damage pay to clean it up. Unfortunately, however appealing such a solution may be, it must be rejected because it carries within it the seeds of its own failure.

To see this, suppose that a carbon tax were implemented in the high income countries which emit most of the GHG's. A truly effective tax would result in lower consumption of oil, coal and other fossil fuels with a consequent reduction in fuel imports. This would inevitably lead to lower prices on international markets for these fuels and would create exactly the right incentives for currently low income countries to grow and develop in the same fuel-inefficient manner as currently rich countries have done. (See Bohm 1990a and 1990b for a discussion of this problem)

It follows that in order to achieve the goal of reduced emissions of GHG's all countries must be involved. However, the costs to each of doing so vary widely and depend not only on the type of policy proposed, but also on the structure of their economies and the level of development achieved. Since any international agreement will be negotiated by national governments, success requires that each country see that the final accord is both in their interest - in the sense that the national calculation of costs and benefits is positive - and that it is equitable - in the sense that everyone's contribution is in some sense fair when compared to other countries.

This paper analyses the factors which cause these costs and benefits to vary from country to country. In order to achieve a viable agreement, it will be necessary for each country to see a positive outcome in the long run, which is the natural time horizon to consider when analyzing policies intended to have long run effects in addressing what is in fact a slowly developing problem. This paper addresses the likely consequences of a carbon tax on economic growth in different countries and the resulting change in the ability to achieve important goals such as poverty alleviation or equitable income distribution.

These factors will be key in controlling population growth, since poverty and population pressure are important determinants in direct degradation of forests and croplands (See, for example, Southgate (91)). In addition, though poor countries currently consume little energy per capita, largely because they are poor, their primary goal for their citizens is to raise their welfare above subsistence levels. Doing this without exacerbating environmental problems will be the true challenge in devising an acceptable long run strategy.

However, in addition to analyzing the long run, as has been the rule in previous studies of this issue, it is also important to analyze the impact effects of, e.g. a carbon tax, on different sectors of the economy because this impact effect can reveal a great deal about the political feasibility for current leaders of signing on to an agreement. These leaders must of necessity take a much shorter view on any matter than does the typical economic analysis since political requirements for staying in office do not hinge on policy results in the next century.

One particular problem facing an accord is the likelihood that even though there may be long run benefits to participating in an accord, negative consequences for growth and for some sectors of the economy will dominate in the short run. Accordingly, this paper will also address the political economy of carbon taxes and the extent to which winners and losers within a given country can affect the likelihood of achieving a truly global agreement.

The question posed here - the differential effects of a carbon tax in different economies - assumes that each country will in fact promote conservation by providing appropriate incentives to its internal economy. Use of carbon taxes provides an efficient way to achieve emissions reduction and so provides a more conservative estimate of costs than would an analysis of less efficient bureaucratic regulatory approaches.

This takes the issue one step further than proposals such as traded emissions permits. In such schemes governments trade permits and international transfers result. However, the question is left open as to whether recipient governments would actually act on the incentives created and implement policies to reduce carbon emissions. It is far from clear that they can significantly affect such activities as deforestation, but it is clear that they can affect incentives for energy use. This paper discusses the cost-benefit calculation for developing countries in implementing such policies in order to reach a judgement as to whether they are likely to participate in global agreements.

II. Previous Studies

Previous work on carbon tax proposals have focused mainly on the taxes required to achieve a specified level of emissions in a future year, where baseline emissions are determined by a calculation of the energy requirements (given current and/or foreseeable trends and technologies) needed to achieve desired growth rates in national income. See, for example, Hoeller et. al. 1990, Manne 1990, Manne & Richels 1990a and 1990b, Marks et. al. 1990, and Sathaye & Ketoff 1990.

However, it is likely that higher energy prices in and of themselves are likely to render desired rates of income growth unattainable. Hogan & Jorgenson 1990 address this issue in the case of the US but do not go into any detail regarding the likely differences in adverse growth effects between countries of different structures or income levels. It is clear that policy makers in low income countries must consider both problems: the sectoral distribution of costs and benefits in developing countries (as in, e.g. Sathaye & Ketoff) and the long run effects on productivity and growth. The majority of studies taking a global view do not disaggregate sufficiently for the differences in structure in developing countries to be distinguished.

Historically, countries at different levels of per capita income have different energy requirements for increments to national product. For example, an economy whose growth is primarily in the services sectors (e.g. the U.S.) is likely to have a much lower energy intensity of GNP growth than is a country just embarking on the task of building a transportation system, electrical grid and industrial plant. Figure 3 shows how the energy intensity of growth has changed over the past two centuries, and projects a similar inverted "U" shape for developing countries in the future, with technological advances allowing an overall reduction in the absolute level of energy required to support given rates of growth.

Fortunately for the purposes of this paper, there have been numerous studies of the short and long term effects of energy price shocks, and this literature has a direct relation to the likely effects of a carbon tax. Falling for the most part on energy products, such a tax would be perceived by most agents in the economy as an energy price increase for those products high in carbon vis a vis non-carbon based fuels. The parallels with the oil price shocks of the 1970's and 1980's are obvious, and analyses which focused on changes in fuel mix and changes in growth paths provide a basis for beginning to evaluate some of the effects of a carbon tax.[2]

There is, however, one big difference between carbon taxes and the recent energy price shock: in the present case, the increase in price is received by the national government rather than by the foreign government. This is not a change in the external terms of trade faced by a country but a change in internal relative prices.[3]

While some analysts have discussed the possibility of taxes imposed by producers of, e.g. oil, a case which is exactly parallel to OPEC's price increases of the 1970's, the idea that such an arrangement could serve as the basis for an international agreement seems so far-fetched that it merits no serious consideration. Nevertheless, it could be argued that developing countries would be eager to sign onto an agreement establishing supranational taxation of carbon if the receipts were directed toward them. Given the world carbon tax base of $43 trillion (Whalley & Wigle 1990) there would certainly seem to be scope for transfers. However, this would depend on the willingness to pay of developed countries, and would in any event be viewed as a greater constraint to sovereignty than a self-imposed tax.

This would mean that the negative effects of the carbon fuel price shocks are offset to some extent (at least on the national level) by a revenue windfall for the government. Presumably, this windfall could be used to promote the types of investment required to best adjust to the new relative prices after imposition of the tax. In fact, the way the windfall would be spent would be likely to vary from country to country depending upon the spending priorities of the government. These priorities could range from the investments mentioned to general deficit reduction, debt repayment or the oft cited culprits of "waste, fraud and abuse". It is almost inevitable that one result will be an increase in inflation since a carbon tax is felt on the supply side as a negative shock while on the demand side there is either no effect or a positive one depending on how governments use the resulting revenue.

While a precise definition of the uses to which revenue would be put is not possible, it is important to acknowledge that such a boon is a powerful incentive to national leaders to join in a global treaty regardless of their own marginal spending propensities. Acknowledging that this tax is an internal transfer highlights the true nature of the costs of adjustment; the problem is one of adjustment to a new set of relative prices where the costs which are internal to the country are those of adjustment (e.g. retooling or replacing capital stock to take best advantage of changed prices) and altered calculations of profit and comparative advantage which can affect the level and sectoral composition of growth. Whether taxes are used to promote adjustment by investing in new technology and conservation or are spent in other ways is an important determinant of the ultimate outcome.

III. Costs and Benefits of a Carbon Tax

Most previous work has focused on the costs of implementing GHG abatement policies as measured from a "current trends" forecast of growth. As discussed in the previous section, the question is not correctly posed as being an issue of how to achieve desired rates of growth since these rates will not in fact occur if the policies are implemented. However, it is equally important to recognize that these growth rates won't occur even if the policies are not put in place.

As noted by Rothman & Chapman 1991, studies must measure from the appropriate baseline. That is, if global climate change truly is threatening enough to warrant global action and coordination on a scale heretofore unprecedented, then we must base our forecasts on a fairly gloomy assessment of what economic growth would occur in the absence of action to address the problem.[4]

However, any such forecast of the effects of global warming remains speculative, since there is no solid basis from which to make global forecasts much less regional or sub-regional ones. This is a consequence of the necessarily probabalistic nature of forecasting, but makes it much harder to formulate a baseline scenario from which to analyze the effects of abatement policies. Given the focus of this paper on the costs and benefits for politicians of reaching an agreement, it is questionable whether such long range and speculative effects matter in the least, particularly when their own actions in isolation have little or no detectable effect on the problem (if, as is the case with most, they live in a relatively small country in terms of GHG emissions). Nevertheless, even if we assume that politicians do in fact care about the long run net effects, they still must necessarily deal with short run costs of making a carbon tax agreement.

The remainder of this section will focus on the costs of agreeing to impose a carbon tax, both from a distributional point of view and in terms of its effects on growth. In particular, the interaction between carbon taxes and countries' "other agendas" such as poverty alleviation, debt repayment, as well as other environmental and social issues such as deforestation or migration. This will be followed by a description of the benefits of participating in an agreement, both in economic terms and in terms of the environment.

Distributional Effects of a Carbon Tax

The distributional effects of a carbon tax would initially fall most heavily on nations which emit the most carbon, mostly from energy use. It is clear that at the outset, this would mean that the industrialized countries in the OECD and in the former Eastern bloc would be most severely affected in absolute terms.

The fuel mixes for different regions differ widely in their reliance on different types of fuels. Given the following average carbon content per million BTU of each fuel, it is clear that a carbon tax will hit some regions far more than others:[5]

	kg of Carbon/10^6 BTU
Coal	25.4
Oil	21.0
Natural Gas	14.5
Nuclear	0
Hydro	0

Figures 4a-4d show that consumption of carbon bearing commercial energy products are a far greater proportion of total energy in many poor countries than in rich ones. Many developing countries in general rely heavily on oil, especially for some activities where there are few substitutes, as in transport. China is an exception to this, possessing and consuming large amounts of coal. The large hydro potential in Latin America is a plus from the point of view of a "GHG conscious" fuel mix, but reliance on new hydro facilities carries with it its own environmental problems. In Brazil for example, the largest economy in Latin America, plans to build new dams in the Amazon region have met with strong resistance from environmentalists and defenders of the rights of local populations.

Figure 5 shows the share of carbon emissions accounted for by different sectors of the economy in selected countries accounting for a large share of energy use and population in low income countries. (China, India, Korea, Indonesia, Argentina, Brazil, Venezuela, Mexico, Nigeria) It is clear that industry, transport, household use and electricity generation are the most important. In terms of the productive sectors of the economy, it is obvious that the more energy intensive activities (metals, paper, stone clay & glass, etc.) will suffer the most. These industries are by no means spread equally across countries; much of the difference between countries depends on their resource base in addition to their level of development. What seems clear, however, is that countries which have previously exhibited a comparative advantage in energy intensive products will bear the brunt of the burden <u>except</u> in cases where there are large non-carbon energy sources such as hydro or nuclear.

There is a strong relation between income and energy use not only between countries but also within them. One study of Brazil (Januzzi 1989) showed that only 30% of the households accounted for about 70% of energy use. Most of these 30% were in urban areas. Also important is the heavy reliance of lower income households on fuelwood. Though there has been a decline in use of this fuel in most countries as incomes rise and as commercial fuels replace traditional ones for the urbanizing populations, it is unlikely that a carbon tax could be successfully collected on fuelwood or other forms of biomass.

In fact, urbanization per se is an important factor in increasing per capita energy consumption both because of greater availability of commercial fuels, and the need to rely on more energy-using services such as busses, lighting, etc. This fact means that more urbanized countries, such as those in Latin America, will be hit harder than more rural ones, such as those in Africa and to some extent Asia.

If the shift from traditional to commercial fuels is delayed or reversed, carbon taxes might contribute to another major environmental problem: deforestation. This is likely to remain a major concern in large parts of the developing world even without the imposition of a carbon tax and should be a consideration in evaluating the effects and desirability of carbon taxes. In fact, the shift toward such traditional fuels can occur through channels other than household shifts; If, for example, more expensive commercial fuels mean slower growth in manufacturing/industrial sectors of the economy, this can affect internal migration rates out of agriculture or toward frontier areas where traditional fuels are used.

In summary, carbon taxes are more onerous for:

- countries which rely disproportionately on fossil fuels
- countries with large transport sectors
- more urbanized countries
- higher income groups

- countries with large heavy industry sectors

- countries where more expensive commercial fuels would promote deforestation caused by using firewood.

Carbon Taxes and Growth

As noted in the introduction, much previous work analyzing the effects of carbon taxes have used trend macroeconomic growth rates as a starting point. However, the experience of the 1970's and 1980's with large changes in energy prices makes it clear that there are likely to be substantial income effects from imposition of energy taxes. This is true even though the adverse terms of trade impacts of the energy price shocks of the 1970's would not result from a carbon tax.

In comparing the effects on different countries, it can be seen in Figure 6 that the energy intensity of GNP varies systematically with the level of per capita income. This figure illustrates a regression based on a cross-section of countries at different stages of development in which per capita income is used to explain per capita energy consumption.[6] Comparing this with Figure 3, it is evident that the rising and then falling energy-intensity of per capita income characterizes the current pattern of world energy use as well as over time in the currently developed countries. Those countries using a lot of energy per capita would feel the greatest shock from a tax, while those low and middle income countries engaged in building energy using infrastructure such as a manufacturing base and modern transportation system will experience the greatest adverse effects in term of growth.

Higher energy prices mean that energy intensive activities will be undertaken at a lower level and are likely to be delayed somewhat in terms of their "typical" place in the growth path. All of this means that the cost in terms of growth foregone will vary according to countries' income levels. Given the common finding in econometric studies that energy and capital are complementary inputs, a tax on energy will reduce the rate of return on capital and so retard capital accumulation and growth.

Various studies have explored this relationship. Dahl (91) surveys studies of energy/output elasticities, and a summary of these results is shown in Table 1. It can be seen that estimates of the short run elasticity of commercial energy with respect to output is 0.47, but rises to 1.19 in the long run. For industrialized countries the long run elasticity is a bit lower at 0.93. Both developing and industrialized countries show substantially higher output elasticities for residential than for industrial use, supporting the point made above that there are likely to be strong effects on the pattern of production in the event of the imposition of a sizable tax. However, the price elasticities for industry are higher than for residential uses in developing countries in the long run.

The most striking aspect of Table 1, and one which should give supporters of carbon taxes some pause, is that energy demand seems to be generally price inelastic but income elastic. This means that the adverse effects on growth are likely to be substantial compared to gains in reducing use of carbon fuels. This somewhat bleak outlook is tempered to some extent by the average elasticities for oil, where for industrialized countries usage is both price and income elastic in the long run, suggesting that there would be a strong tendency to substitute non carbon fuels such as nuclear or hydroelectric wherever possible. The picture for developing countries is quite different however, with low price elasticities and high income elasticities.

Hoeller et. al. (1990) report results from a survey of country studies of the effects of carbon taxes which find growth rates reduced between 0.1% and 1.5% in the long run, resulting in levels of GNP from as little as 0.6% to more than 15% lower by the year 2000. It is likely that these costs will be front loaded in that growth rates are likely to suffer more in the short run as old energy inefficient capital must be scrapped and replaced. Estimates of the short run effects on GNP are few but the elasticities reported above indicate that a cost of 1% to 2% of GNP is a conservative estimate of the likely results of a tax such as that discussed here. (See, for example, Nordhaus 1990 and Schelling 1992.)

Benefits from Carbon Taxes

Clearly, the most important benefit would be avoidance of the adverse effects of global warming. Among these are changes in cropping patterns, flooding of coastal areas requiring relocation of large populations and loss of major infrastructure, and health effects. It is not within the scope of this paper to go into great detail on these disaster scenarios but it is obvious that, if indeed there is a high probability that they will occur (something that is open to debate) then avoidance of them is a major benefit. Insofar as a higher proportion of the population in developing countries is directly dependent on climate for sustenance due to the large share of agriculture in the economy, these benefits may well be more important for poor countries than for rich ones.

However, there are some additional benefits that can be foreseen which do not depend on necessarily uncertain projections of climate change on a regional basis. First, there would be substantial increases in the efficiency of energy use, and consequently the operating costs of energy using machinery would be lower, at least in pre-tax terms. While forecasting technological changes is chancy at best, it is a safe bet that higher energy prices would quicken the pace of technical change.

Second, an increase in energy efficiency and decrease in rates of use would result in a stretch-out of the life of known fossil fuel reserves. This would push back the need to find replacement fuels for finite resources even as research into those replacements is being encouraged because of the higher prices resulting from the tax. In addition, there would be less pressure to look for fossil fuel reserves in environmentally fragile areas such as wildlife refuges or sensitive off-shore sites.

Finally, a decrease in fossil fuel needs would mean a decrease in dependency on imports for the majority of countries which have inadequate or no reserves of their own. This would reduce pressure on the balance of payments and permit increases in imports of, e.g. capital goods or other needed inputs. The value of this benefit would be proportional to a country's current fuel imports.

One common characteristic of all of these benefits is that, though substantial, they are only evident in the long run. In the short run there are likely to be substantial costs needed in order to be in a position to benefit in the future. For example, in order to gain the benefits of higher fuel efficiency, lower import bills, and avoidance of adverse climactic effects it is necessary to replace current fuel using capital with new more efficient capital. This capital cost is incurred in the short run, and can be quite substantial. As was noted above, even if the present value of these investments is extremely attractive, the short run balance of costs and benefits is likely to be negative.

IV. What is Needed to Get an Agreement?

When all of the considerations discussed above are added up there are several major obstacles to achieving a global agreement to impose carbon taxes. First and foremost is the fact that there are wide differences between countries in the costs and benefits of agreeing to such a tax. This could be dealt with through inter-country transfers, but even then there are some additional problems.

First, is that even if all of the costs and benefits are added up, and the calculation looks good from a particular country's point of view, the timing of the costs and benefits are not likely to be attractive. In other words, even a positive present discounted value can be rather uninspiring when there are large costs up front and the benefits are delayed and are in any case speculative. Given the inability of most developing countries to access world capital markets to begin with, this could pose a problem.

Second, many of the costs are out-of-pocket while the benefits are less tangible or are merely costs to be avoided. Governments, who are the ones at the negotiating table, worry more about direct expenses and less about ones that don't appear in their budgets. Taxes, from this point of view, are nice for governments since they add to revenue, but are bad for business since they add to costs. Thus there is likely to be a big difference of opinion within countries as to the benefits of joining a carbon tax agreement.

If, as is argued above, there are likely to be costs in the short run regardless of one's view of eventual net costs and benefits, there will be a financial burden on countries trying to implement carbon taxes. These costs are likely to be out-of-pocket since a large fraction of the expense consists of replacing outmoded capital equipment. What is especially important from a policy point of view is that increased capital expenditures need to be financed, and this implies an increase in debt (foreign debt if capital equipment is imported). There will also be pressure to cushion the impact of negative growth rates by borrowing during the process of adjustment.

Most developing countries are already constrained in world capital markets in that they cannot borrow readily. Additional funds could be provided on a concerted basis by industrialized countries if a political decision were made to do so; voluntary private flows of capital are not likely to respond. How much would be needed? The analysis above suggests that 1% of GNP is a conservative estimate of the costs in terms of growth foregone in the short run. A quick calculation reveals that in order to finance this amount for low and middle income countries (as defined by the World Bank, excluding oil exporters) for one year, a total of $23 billion would be required. If costs are longer lived than one year, this figure would of course be much larger.

Can the developed countries realistically hope to provide this much in credit in order to make it possible for low and middle income countries to make needed investments resulting from imposition of a carbon tax? This figure is put into some perspective when it is noted that $23 billion is approximately equal to total annual lending by the World Bank in recent years. It is not impossible to imagine doubling the size of this lending program, but it must also be admitted that it is not likely. The current U.S. administration has said that it is willing to spend only $75 million for this purpose. Clearly, there is a large gap between this figure and what might realistically be required.

This observation naturally invites speculation regarding the possibility of retiring international debt in return for implementation of a carbon tax. While this idea may have some merit, there are some fundamental problems earmarking debt retirement for carbon tax compensation. First, if one takes the view that the debt is unpayable to begin with, then it will sooner or later be retired or eliminated without need to agree to a carbon treaty. Second, the distribution of debt is not the same as the distribution of effects resulting from a carbon tax. Third, insofar as retired debt is owed to private creditors, it is unlikely that they will voluntarily renounce contractual claims of any value without compensation. To transfer hard currency to creditor banks to retire unpayable debt rather than transferring it to developing countries for whom foreign exchange is a serious constraint seems perverse.

Perhaps more important is the likelihood that most countries would remain unable to access credit markets even if outstanding debt were eliminated. Many countries are currently making no net payments on their debt; they are at best paying interest and often incurring new debt even to do this. The upshot is that there is no net inflow of capital. Were international lenders to agree to write off existing debt it is extremely unlikely that they would then embark on new loans for the purpose of capital replacement pursuant to a carbon tax or for almost any other purpose. Though writing off debt would clearly be a benefit, it would not by itself provide the wherewithal to make needed investments so long as countries remain shut out of world capital markets.

A further problem with debt write-offs, and one that is shared with other redistributive schemes, is that it is neither assured nor even likely that recipient countries would regard GHG abatement as the best way to spend large inflows of resources. There may very well be other investments aimed at promoting economic development which political leaders would regard as far more pressing.

If it is indeed true, as argued here, that the costs for developing countries of joining GHG abatement efforts are likely to be viewed by many governments as prohibitive, and that even if provided the necessary transfers they would not necessarily use them for this purpose, what remains of an international agreement? Pessimistic scenarios include, of course, the specter of general chaos, with coastal flooding and massive disruption of society. An optimistic scenario might include as comprehensive an agreement as could be reached among, for example, high income countries. The optimists' hope would be that this agreement would provide incentives for the development of new technologies which could prove more important for GHG emission patterns in 100 years than any government policy. The pace of technological change over the past 100 years provides some comfort for this view and highlights the uncertainty of the technological assumptions associated with long range projections.

Even if the difficulties associated with using carbon taxes to discourage consumption through the price mechanism prevents their implementation for this purpose, they may still be useful at a much lower levels as a means to fund technology development and to invest in other efficiency measures (e.g. insulation or retrofitting housing). A 1% levy on a tax base exceeding $40 trillion could fund a massive increase in these activities. Though the gains from research & development activities are necessarily uncertain, they are potentially large, while the gains from investing in conservation/efficiency measures are relatively certain, but also potentially large. Though these investments need not be financed via a carbon tax and the direct effects would be negligible, it would have great symbolic value and has the benefit of allowing a common approach to the problem at relatively low cost for most poor countries.

NOTES

1. Though many analysts have pointed to biological activities such as agriculture as sources of CO_2, these studies incorrectly focus only on those parts of the biological cycle which result in emissions. In order to emit, a process must also withdraw carbon from its surroundings. So, in cases where the activity truly is a cycle, and not the destruction of a cycle as would be the case if, e.g. a forest were converted to a sterile desert, such emissions must be balanced with uptake; the resulting net releases are likely to be many orders of magnitude smaller than those estimated solely on the basis of a partial view.

2. Among the studies emphasizing the relation between growth and energy use are Ang 1987a and 1987b, Desai 1986, Erol & Yu 1988, Salib 1984 and Yu & Choi 1985. Studies which take a more disaggregated view emphasizing the relation between energy use and economic structure include Behrans 1984, Bohi 1981, Boyd & Uri 1991, Dahl 1991, Fiebig et. al. 1987, Ibrahim & Hurst 1990, Jannuzzi & de Martino 1989, Jones 1991, Kim & Labys 1988, Kim 1986, Koshal et. al. 1990, Li et. al. 1990, Longva et. al, 1988, and Seale et. al. 1991.

3. Indeed, it is likely that the external terms of trade will improve somewhat since a successful treaty would result in vastly decreased demand and prices on world energy markets. See Bohm op. cit.

4. This baseline should in theory be based on the likely effects of global warming if no abatement is pursued. Note that this does not mean a mere continuation of current trends of economic growth, energy use, etc. but a scenario that takes into account effects such as shifts in cropping patterns, flooding of coastal areas, and other results of an adverse effect from GHG buildup. Naturally, not all countries will suffer equally and so there will be a range of incentives to suffer the costs of doing nothing rather than undertaking the costs and benefits of abatement. (See Shue 1990 and 1991 for a discussion of ethical aspects of this choice.)

5. These figures are global averages based on estimates from the Oak Ridge National Laboratory Carbon Dioxide Information Analysis Center, cited in Manne 1990.

6. The regression included all those countries for which Dahl 1991 provided the requisite information, and was of the form:

$$ENPC = \alpha + \beta\ GNPPC + \gamma\ GNPPC^2 + \epsilon$$

where ENPC is 1988 energy consumption per capita in millions of BTU and GNPPC is GNP per capita in 1988 dollars. The resulting estimates were:

	Parameter	T - Statistic
α =	16.54	0.30
β =	0.02	6.52
γ =	-0.55×10^{-6}	3.79
R^2=	0.66	
N =	66	

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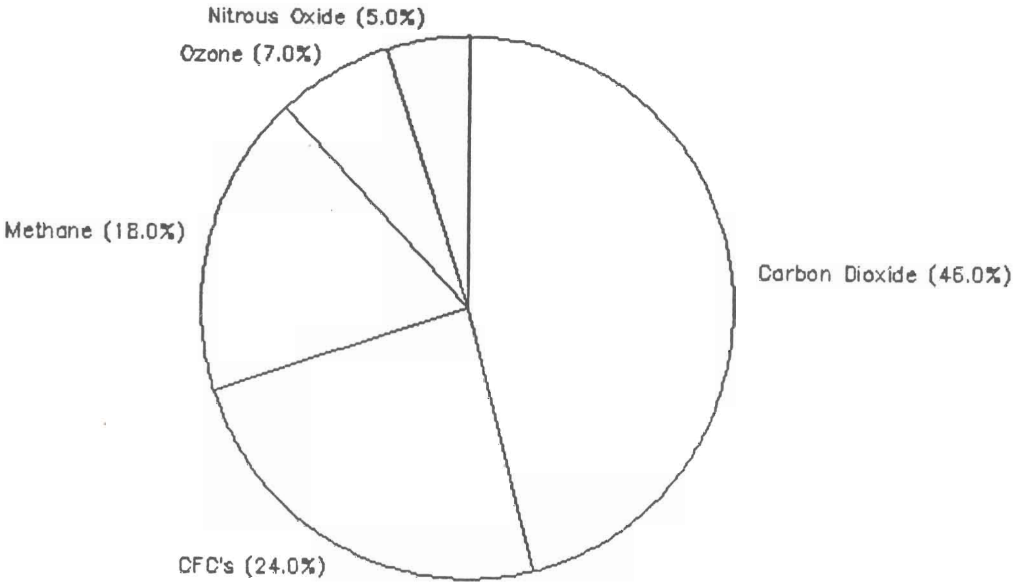
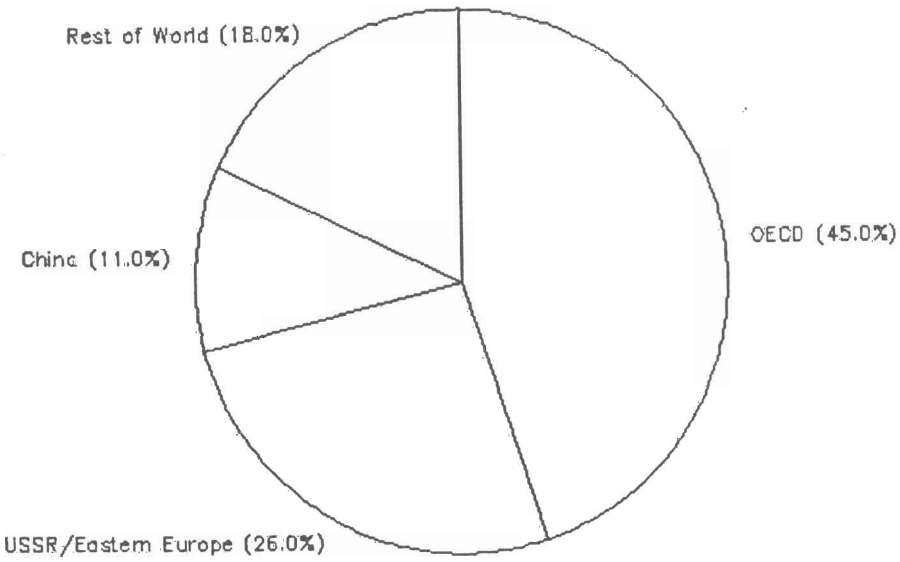
Figure 1 — Contribution of Gasses



Source: Arrhenius and Waltz, 1990.

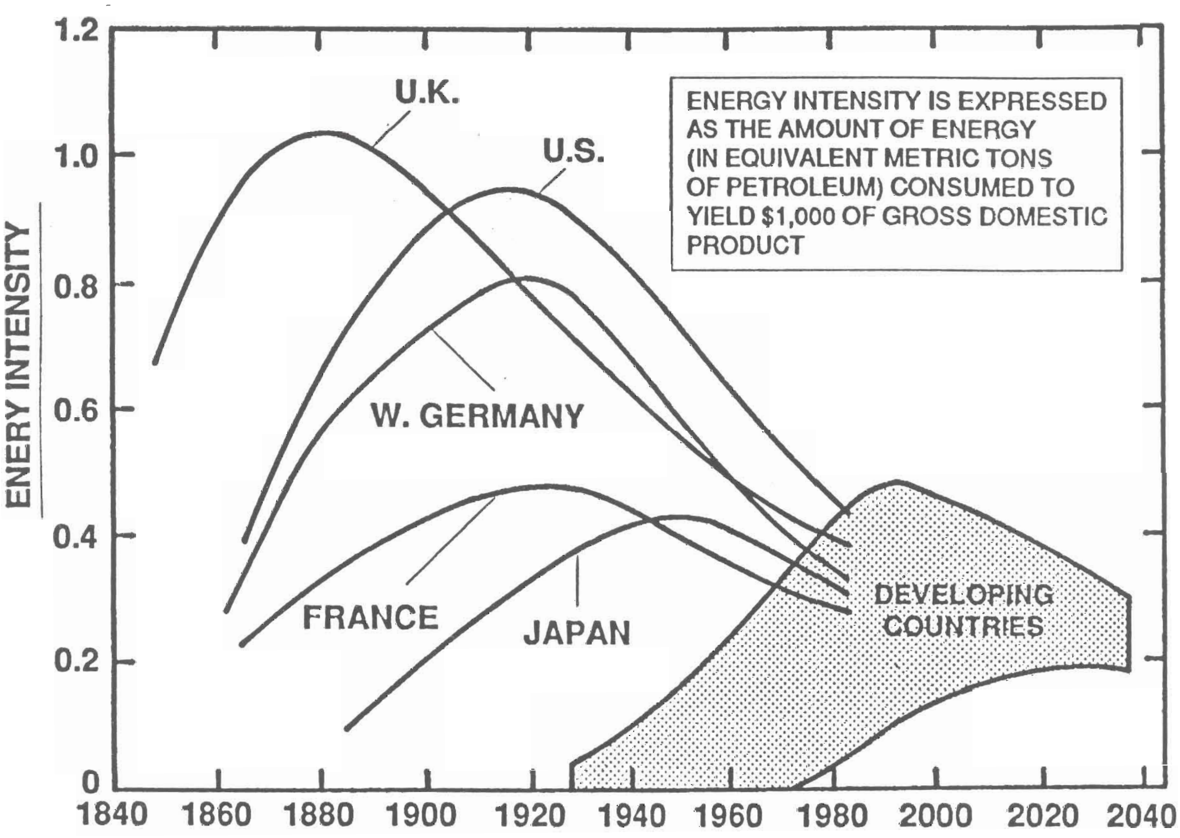
Figure 2 — 1990 Carbon Emissions

(total = 5.7 billion tons)



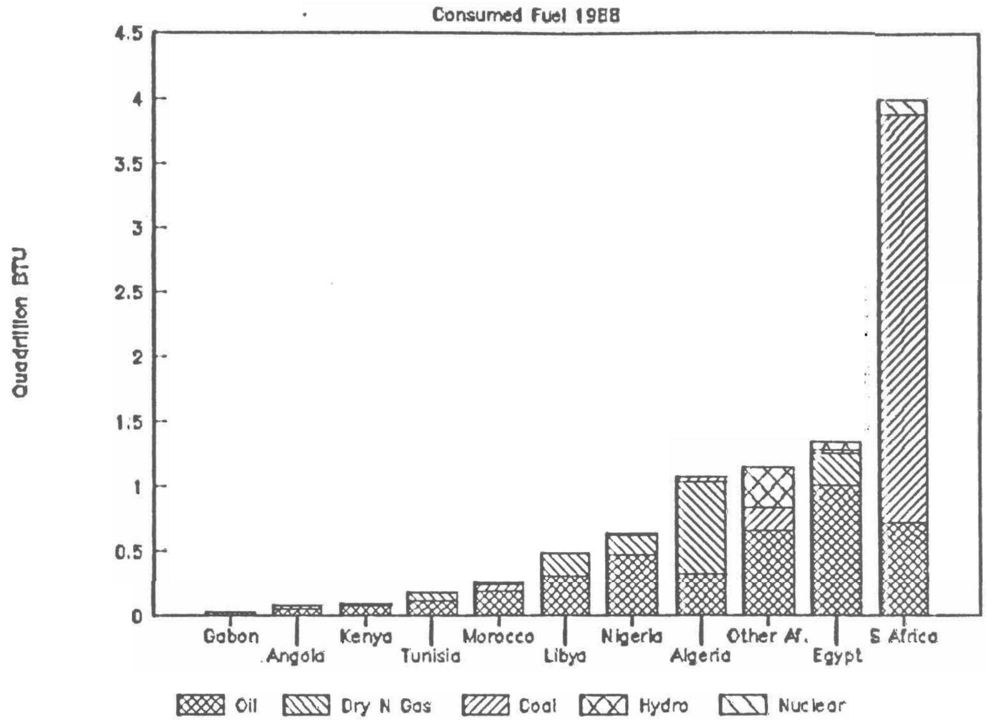
Source: Manne and Richels, 1990.

Figure 3   Energy Intensity of GDP Growth



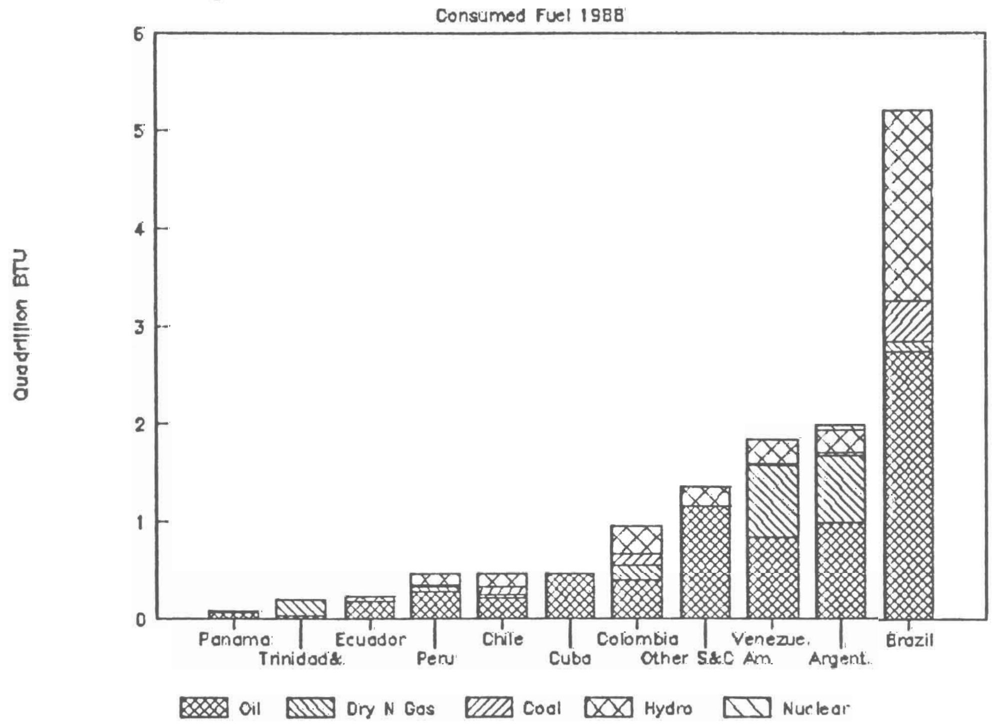
Source: Reddy and Goldemberg, 1990

Figure 4a – Fuel Mix for Africa



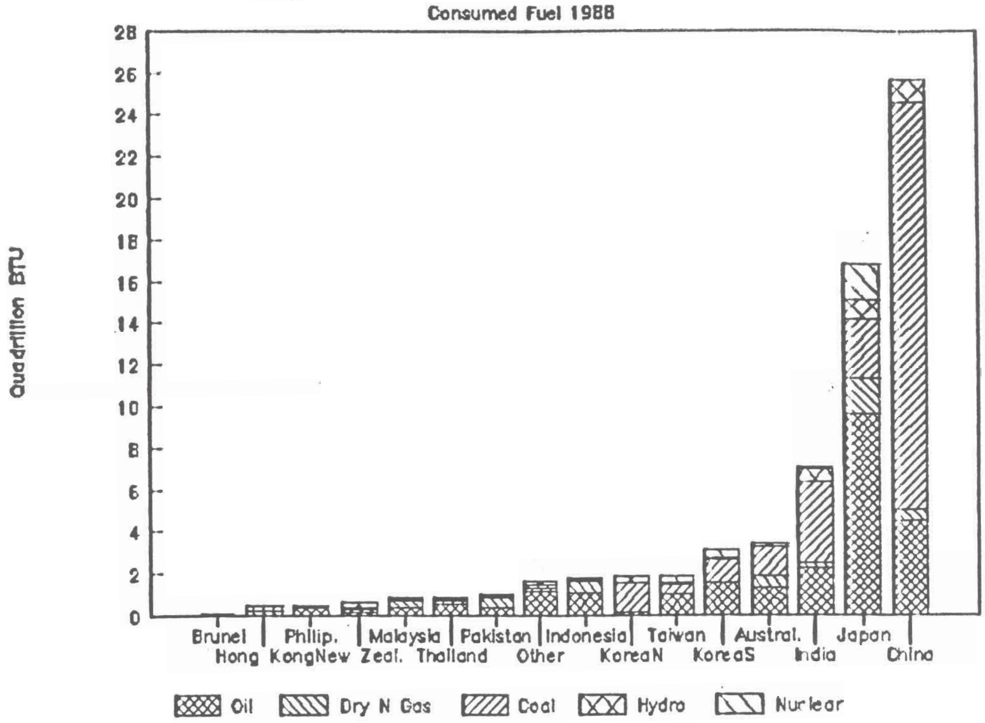
Source: Dahl, 1991.

Figure 4b – Fuel Mix for Latin America



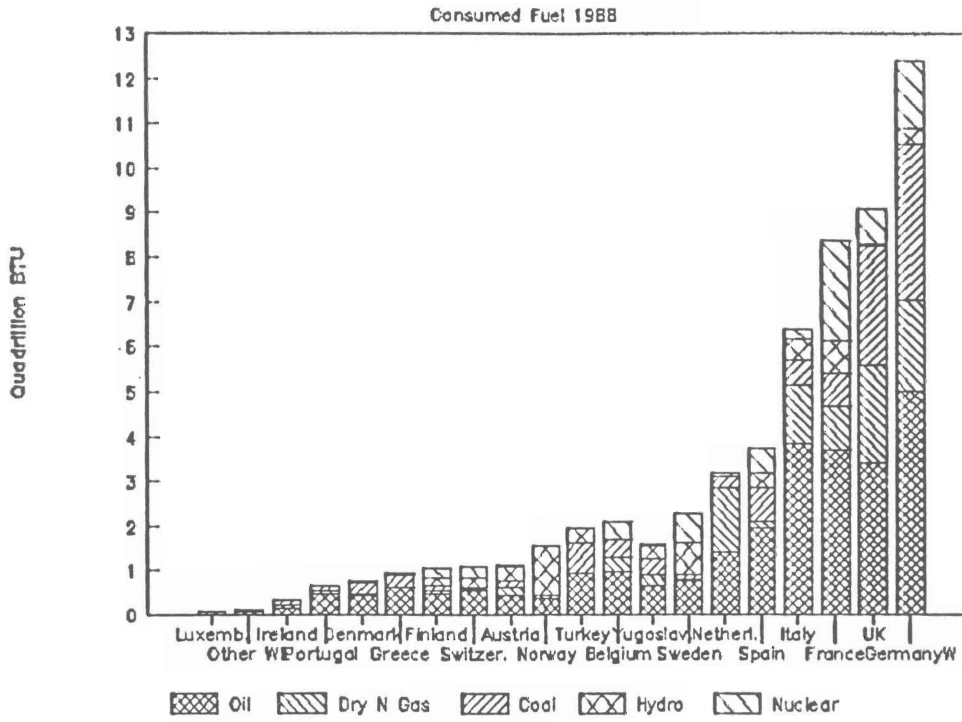
Source: Dahl, 1991.

Figure 4c – Fuel Mix for Asia



Source: Dahl, 1991.

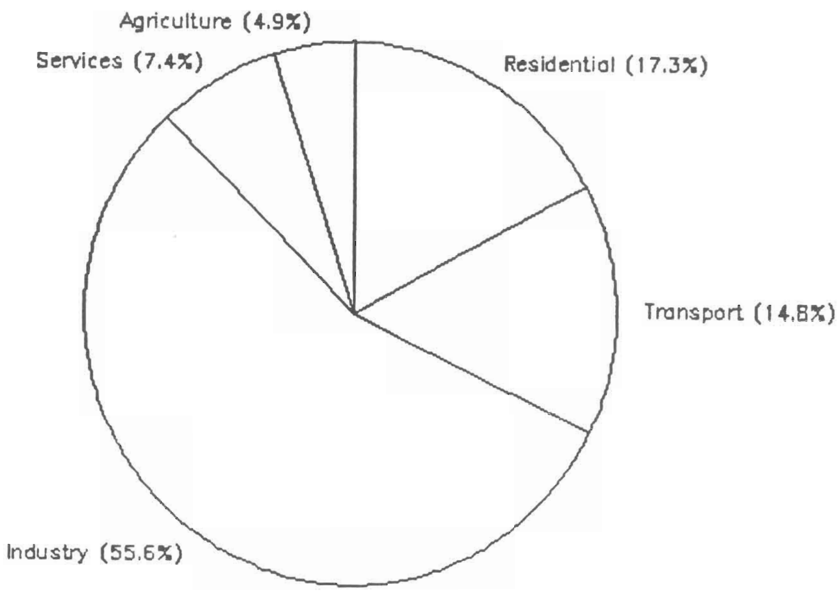
Figure 4d – Fuel Mix for Western Europe



Source: Dahl, 1991.

Figure 5 — Sectoral Shares of Emissions

(Nine Countries)



Source: Sathaye and Ketoff, 1991.

Figure 6 — Energy and Per Capita Income

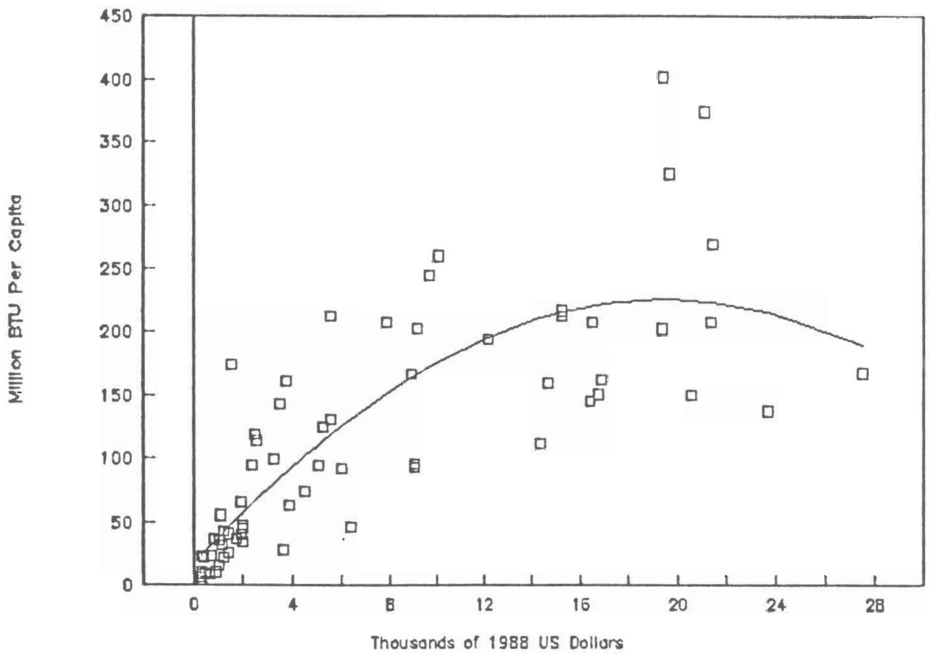


Table 1. Summary of Average Energy Elasticities.

	P_{SR}	P_{IR}	P_{LR}	Y_{SR}	Y_{IR}	Y_{LR}
Developing Countries						
Total Energy	-0.12	-0.38	-0.54	0.45	0.82	1.19
Industrial Use	-0.19	-0.34	-0.50	0.48	1.11	1.15
Residential Use	-0.14	-0.80	-0.27	1.33	1.49	2.48
Oil	-0.06	-0.26	-0.17	0.46	1.10	1.03
Industrialized Countries						
Total Energy	-0.22	-0.50	-0.45	-	1.13	0.93
Industrial Use	-0.24	-0.57	-0.35	-	0.88	0.84
Residential Use	-0.23	-0.59	-0.74	-	1.45	0.99
Oil	-0.35	-0.88	-1.01	-	1.59	1.35

P_{SR}, P_{IR}, P_{LR} - Short, intermediate and long-run price elasticities.

Y_{SR}, Y_{IR}, Y_{LR} - Short, intermediate and long-run output elasticities.

Source, Dahl, 1991.

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