More Motion, More Speed, More Emissions: Will Increases in Carbon Emissions from Transport in IEA Countries Turn Around?

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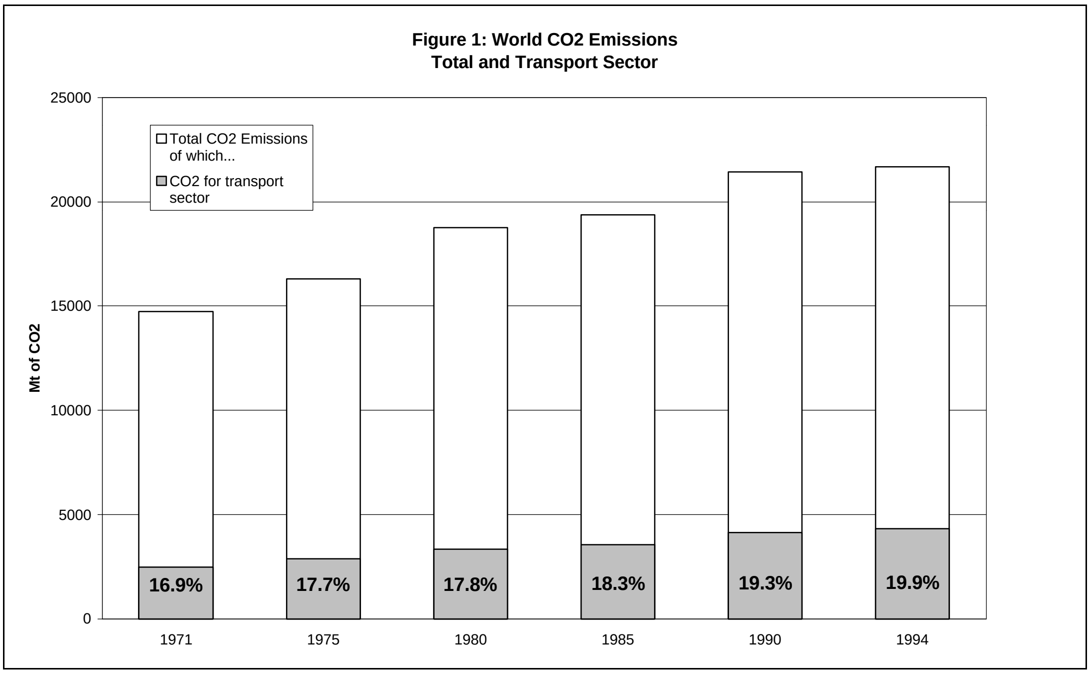
1 - THE CO2 PROBLEM: THE POLICY IMPERATIVE AFTER KYOTO

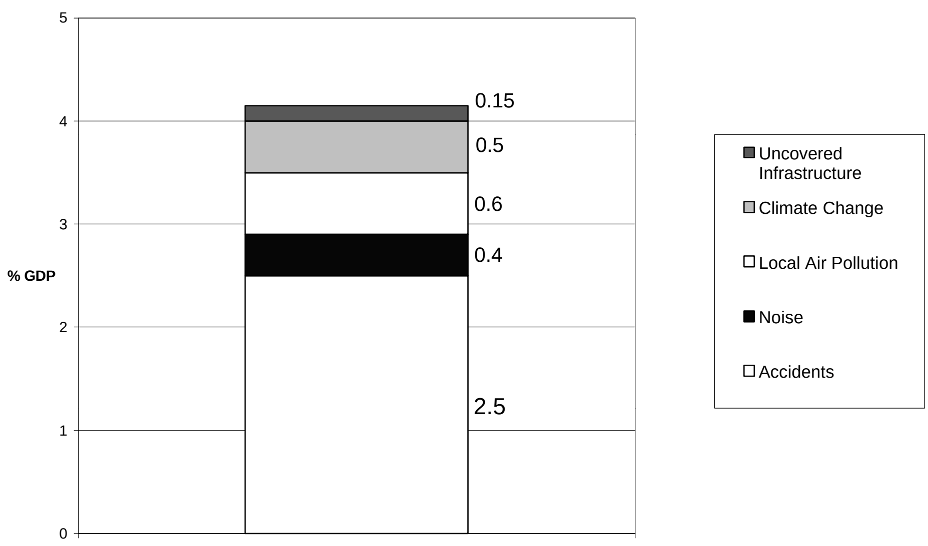
Figure 1 shows the growing role of the transportation sector as a source of CO2 emissions from energy use. This role had not gone unnoticed before the Kyoto and Buenos Aires Conferences of Parties. In this review we highlight the key trends in transportation and carbon emissions that make restraint of those emissions so enigmatic for policy-makers.



Source: IEA

Transportation has long been associated with environmental and other problems beyond CO_2. These include safety, air, water, and noise pollution, competition for urban space, balance of payments problems and risks associated with importing oil as the main transport fuel[1]. While few doubt that transportation returns a huge surplus to every economy, there are segments of transport activity where real social costs are greater than the benefits accruing to drivers or shippers. This was emphasised in a study organised by the European Conference of Ministers of Transport (ECMT 1998). That group concluded “Significant welfare gains could be realised through an adjustment of charges and taxes to provide incentives for reducing the external costs of transport”. They estimated that current welfare losses amount to “several points of GDP”. This is shown in Figure 2. Internalisation of those costs, through both direct charging and some regulations, could have a significant restraining impact on the system in the long run.

Figure 2: Average Estimates of Total External Costs of Road and Rail Transport



Source: ECMT

In this context, the emissions of greenhouse gases have not been ignored in major national environmental strategy documents[2]. Whatever the "real" external costs of each mode, studies suggest that the values attached to the externality for GHG emissions alone tend to be low compared to those associated with other problems. This suggests that CO_2 by itself may not be "felt" as a strong stimulus for change, but that changes to deal with the other problems may affect traffic and therefore CO_2 emissions perhaps even profoundly. The other externalities in transportation may be more serious than CO_2 in the short run. These threats, whether real or perceived, stimulate constituencies to press today for or accept imposition of "solutions", by which technologies and policies could be brought to bear to reduce the problems.

CO_2 emissions, by contrast to other external effects, present no obvious problem for the present generations, particularly as there is some debate about timing and extent of damage we face. Not surprisingly, there may be any <u>strong</u> forces to restrain emissions. Still, policy-makers from some spheres are under pressure from certain constituencies to affect transportation's rising CO_2 emissions now. This paper is about the challenge they face from passenger transportation.

2 - TRENDS IN TRAVEL

2.1. Underlying Factors Affecting CO2 Emissions for Travel and Freight: A Decomposition Approach

A framework is needed to understand factors affecting CO_2 emissions from transport and differences among countries[3]. Lawrence Berkeley National Laboratory has carried out an index decomposition of the factors underlying changes in CO_2 emissions from both freight and travel, as well as from other sectors[4]. All these methods start from a basic formula (Schipper and Lilliu 1999). Consider that

$$\mathbf{G = A * S_{\mathit{i}} * I_{\mathit{i}} * F_{\mathit{i,j}}} \tag{1}$$

where **G** is the greenhouse gas (carbon) emissions, **A** is total travel activity, **S** is a vector of the modal shares I, and I is the modal energy intensity of each mode *i*. The last term $\mathbf{F}_{i,j}$ represents the sum of each of the fuels *j* in mode *i*, using standard IPCC coefficients to convert fuel (or electricity) used back to carbon emissions.
The modal energy intensity term itself is composed of several components:

$$\mathbf{I_{\mathit{j}} = E_{\mathit{i}} * VC_{\mathit{i}} * CU_{\mathit{i}}} \tag{2}$$

where E is technical efficiency, VC vehicle characteristics, and CU capacity utilisation for each mode *I*. Taking only E and VC yields what we call vehicle intensity, or fuel/kilometre.

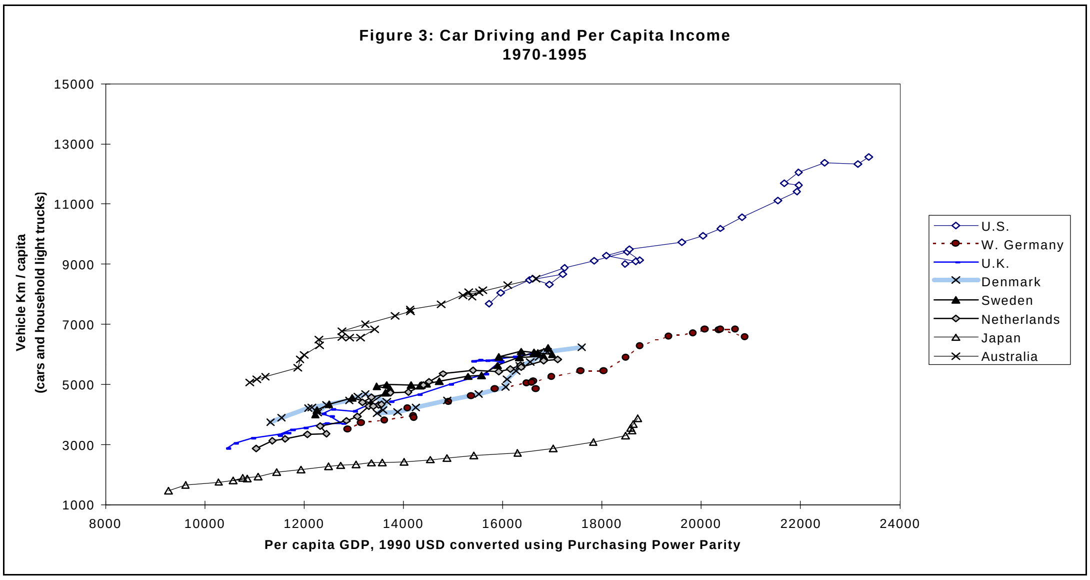
Technical efficiency is the energy required to propel a vehicle of a given set of characteristics a given distance, and is affected by the motor, drive train, frictional terms (including drag), etc. For cars, car power, and technical efficiency could represent characteristics by energy use per km per unit of power. Capacity utilisation would be measured as the number of people per vehicle.

All three of these components share in determining how much energy is used to transport a person one kilometre by each mode. Driver behaviour and traffic conditions affect technical performance. And larger, more powerful vehicles often stimulate drivers to make the vehicles perform, i.e. go faster. Thus some terms in this decomposition that are nominally "technical" – energy intensities – have important behavioural components. Total travel and modal choice are obviously "behavioural" factors, too. The same is true for changes in power, or changes in traffic and driver behaviour, all of which affect how technology turns energy into mobility[5].

Feedback between these components is important, but not major in the countries we have studied. Unquestionably lower driving costs per km, whether brought on by lower fuel prices or lower fuel intensities, encourage more driving. But the elasticities are only modest: 10% lower costs lead to somewhat more than 1% more driving in the U.S., to perhaps 2-3% more in Europe, with the average around 0.2-0.25% (Johansson and Schipper 1997). Lower costs of using cars discourage use of other modes, as can be seen by comparing relative fuel and transit costs and relative ridership in different cities in Europe.

2.2. People on the Move

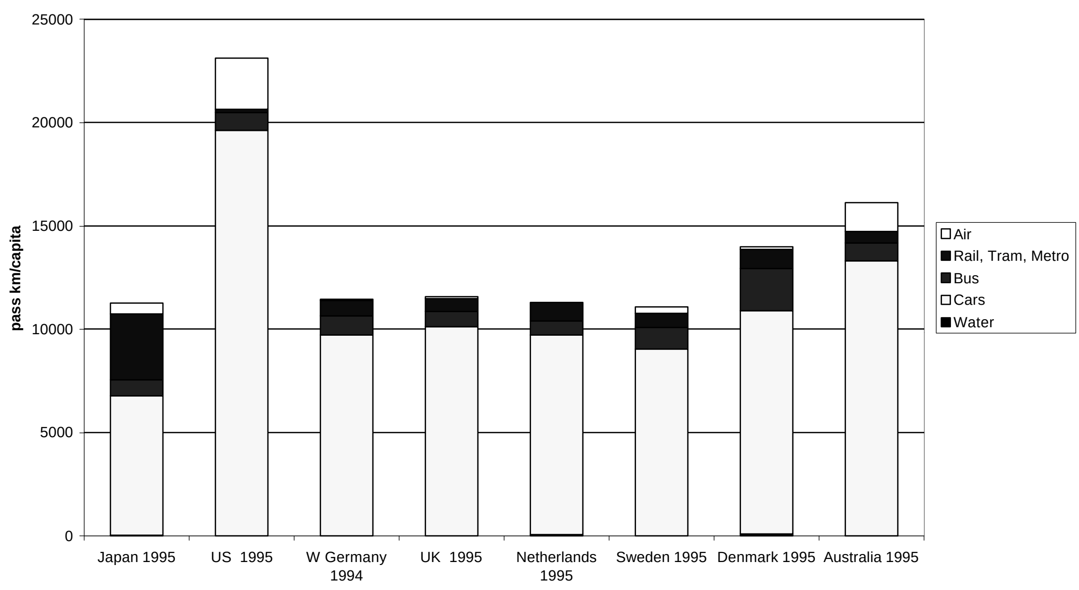
Travel typically accounts for 60-70% of energy use and emissions from transportation. Travel activity **A** is measured in passenger kilometres over each mode **S**i. The key component is automobile travel, and that is driven by automobile ownership. Ownership has risen with income or GDP per capita, although it is showing some saturation in the most motorised countries. Distance travelled per vehicle (vehicle-km, or v-km) is rising slowly with income. Combined, these two forces yield the dramatic coupling of kilometres driven to GDP, as shown in Figure 3 below.



Source: LBNL and IEA

Figure 4 compares per capita motorised domestic passenger transportation in the study countries in 1995 (1994 for West Germany), showing the dominance of the car. Total travel, as expressed by the distance travelled on all modes in passenger kilometres, is "driven" principally by car use. This indicator is rising at a less rapid rate than car use itself because the number of people in a car (load factor) is falling: the number of passenger-km in cars grows less rapidly than the number of vehicle-km covered. Note now how the European countries in the study are bunched together. Relative to GDP, Australia and Canada (not shown), lie with the U.S., while Japan lies somewhat below Europe. If estimates of non-motorised travel were included, the totals for Denmark and the Netherlands would rise by roughly 10%, the other European countries by somewhat less, the U.S. by very little at all[6].

Figure 4: Per Capita Motorised Passenger Travel, 1995

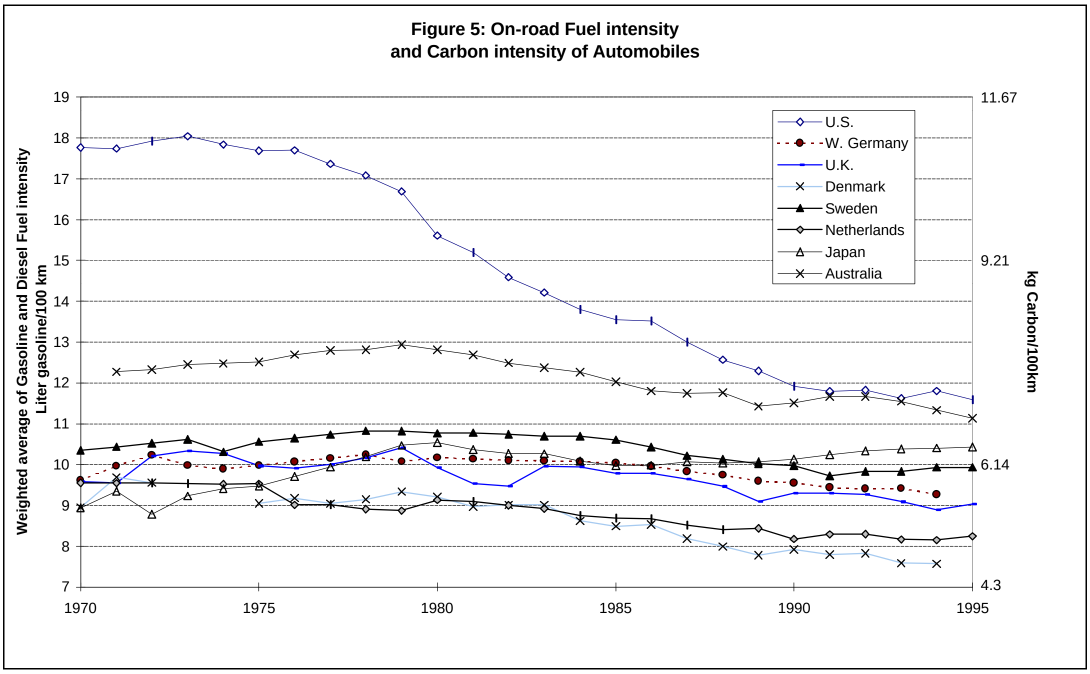


Source: LBNL and IEA

The U.S., Australia, and to some extent Canada (not shown) have roughly similar high levels of total travel, and the same high shares of car and air travel. This suggests that geographical factors play some role in determining total travel. By contrast, the U.K., West Germany and the Netherlands are the most densely populated countries we studied, and have lower levels of travel and car dependence. Japan (not shown) is even more dense (when one considers that most people live on a fraction of the total land area there), and has even lower total travel than the European countries. Economic factors are certainly important, too, as we will note later. While there are important differences among European countries, it is nevertheless interesting how the overall pattern of travel tends to reveal these three groupings as determined by geography.

Closer examination of trends in vehicle fuel use link activity to emissions. We defined the vehicle energy intensity as energy use per vehicle kilometre, and the modal energy intensity as energy use per tonne-km or passenger-km (c.f. Eq. 1 and 2). Vehicle intensity for cars (for a given size and power) is related to the efficiency of the vehicle, while modal intensity depends also on the number of passengers or amount of freight carried. Since cars account for most of the energy use, we will focus on trends in the intensities of these key modes.

Figure 5 shows on-road vehicle fuel intensity, or fuel use per 100 km, for car fleets. Diesel and LPG are counted at their energy content. Emissions/km are shown on the right-hand axis, with the approximation for this figure only that diesel, LPG, and gasoline have the same carbon per unit of energy. Personal light trucks are taken into account in the U.S., as they account for nearly 30% of household vehicles[7]. Fuel intensity fell dramatically in the U.S. (and Canada, not shown), but barely changed in European countries and in Japan. Note that the figures for the early 1990s reflect car fleets that have been almost completely renewed since the early 1970s.

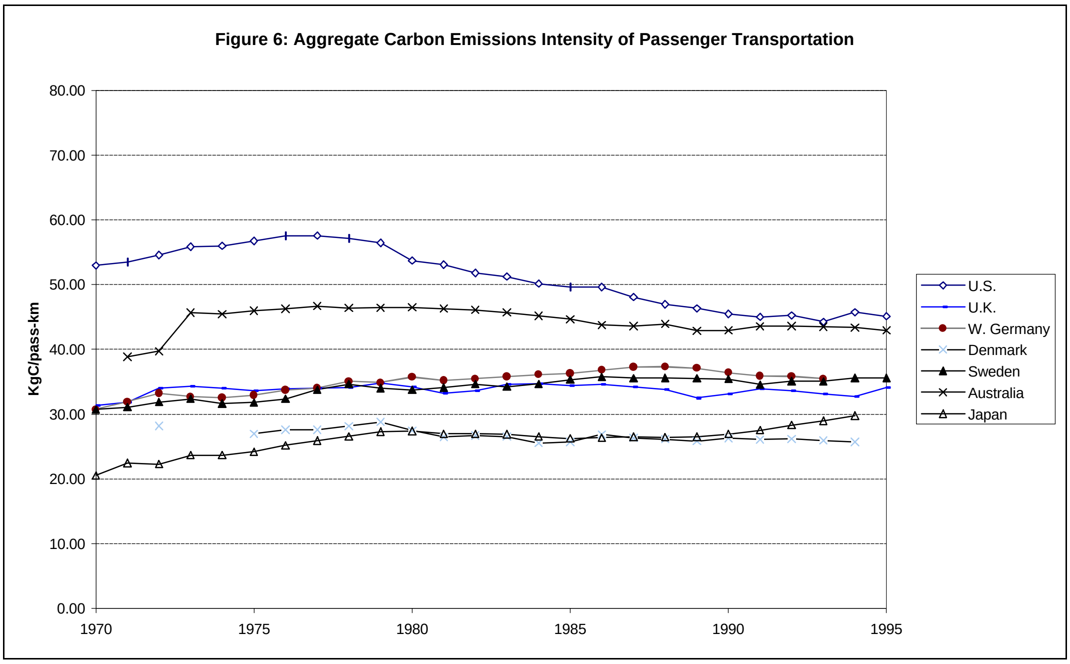


Source: LBNL and IEA

The lack of dramatic change in the vehicle intensities in many countries may be a surprise to many but has a clear explanation: Vehicle performance and weight changes have absorbed some of the savings that advances in fuel consumption technology offer, particularly since 1986 when oil prices plummeted. While new-car fuel intensity is still falling slowly, most technology deployed in new cars in the late 1990s is being used to boost performance, rather than to save fuel. Again, behaviour, abetted by low fuel prices, demands more power, rather than fuel efficiency. This is important for policy, because it means opportunities to save fuel have been foregone.

For air travel, the modal intensities have dropped dramatically. While new aircraft consume roughly 30-40% less fuel per seat-kilometre than those that made up the fleets in the early 1970s, the percentage of seats occupied (load factor) has also risen from around 50% to over 60% for domestic routes in most IEA countries. These changes led to a drop of 50% or more in the modal intensity of air travel, to where it lies close to the value for automobiles.

Car (and air) travel – speed and convenience – propelled the growth in travel. Since these modes require more energy and emit more carbon per passenger-kilometre than bus or rail modes, energy use and CO_2 emissions have risen faster than total travel per capita outside of N. America. Figure 6 shows these patterns (in tonnes of carbon per capita) for travel[8]. The U.S. has the highest emissions because it has both the highest level of travel (with the highest share in cars and air travel) and the highest emissions per unit of travel in cars. Japan (not shown) has low emissions principally because it has the lowest per capita travel and the largest share in rail and bus. European countries tend to cluster between these extremes, albeit more closely to Japan. At first site, then, the U.S. seems to have the most emissions to yield.

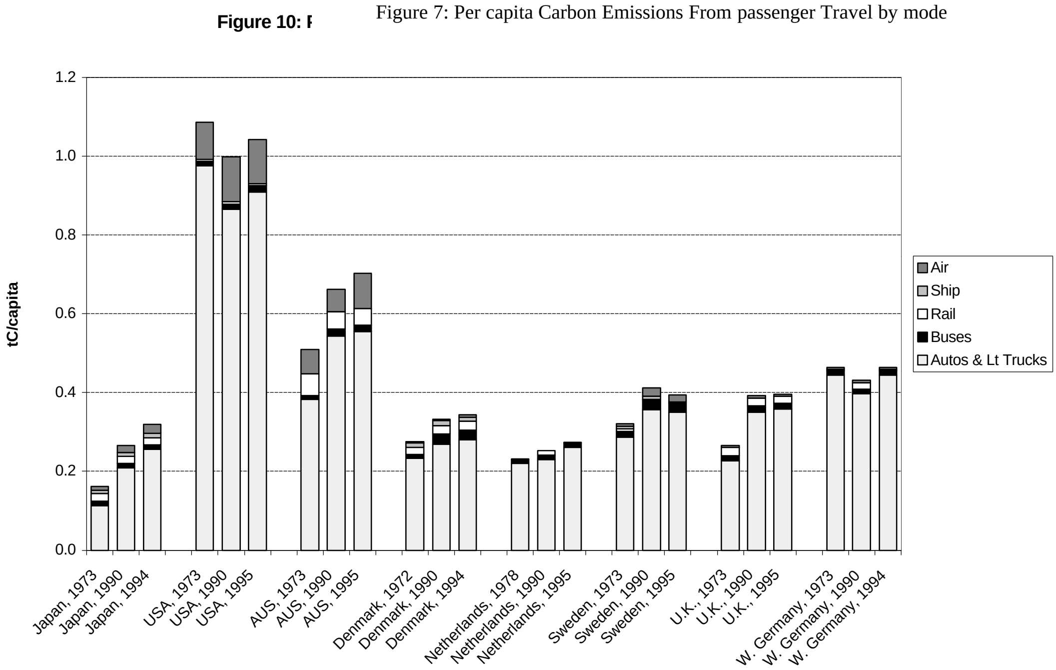


Source: LBNL and IEA

2.3. Decomposition of Emissions from Passenger Transportation

We can aggregate all of the information so far for travel-related emissions. Figure 6 shows that the ratio of emissions to total travel has fallen by about 20% in the U.S. over 25 years, but hardly fallen or even increased in Europe. The reasons are explained by our decomposition of emissions using Eq. 1.

Figure 7: Per capita Carbon Emissions From passenger Travel by mode



Source: LBNL and IEA

For passenger transportation, higher per capita travel (total **Activity**) alone increased emissions in every country, as Table 1, based on Laspeyres indices, shows for the group of aggregates. Modal shifts (**Structure**) towards more energy-intensive modes (cars, air) increases emissions by as much as 25% (in Japan, shown for reference), but in most countries by up to a range of 1 to 3% using the 1990 modal structure as reference[9]. This growth in activity is clearly income-driven[10]. Since car ownership is also income-driven, and car ownership growth lies at the root of the modal shifts, we can say that modal shifts observed at the national level are income-driven as well. And since modal shift itself moves people to more rapid modes and those then move them considerably longer distances (air, for example), we can say that higher incomes are associated with greater and more rapid travel.

Falling **energy Intensities** of vehicles themselves reduced emissions in more than half the countries, but falling load factors in cars (and bus and rail in many countries) offset this restraint, leading to a net increase in energy use (and CO_2 emissions) per passenger-km in cars. Indeed, only in N. America were the emissions savings from lower modal intensities greater than 20%. Changes in Europe and Japan were small because power and weight increases offset most of the impacts of technical improvements. And in all countries, falling load factors in cars, as well as in many countries on buses and rail, also increased emissions. These factors combine to give the changes in energy intensities shown. Shifts in **Fuel mix** and utility mix (not shown separately) had almost no impact, for two reasons. First, the emissions per unit of energy released from diesel and gasoline are very close, although diesel is slightly higher[11]. Second, the role of electricity for travel (rail, trams) is so small that even the almost complete transition away from fossil fuels in some countries (Sweden) had only a very small impact on emissions from this sector. Combing the energy intensities and fuel factors yields **carbon intensities**. Thus by 1994/95, incomes and behavioural factors had clearly increased CO_2 emissions, even after over a decade of relatively high road fuel prices.

Table 1: Carbon Emissions from Passenger Transport
Average Annual Change of Impact of each "ASIF" Factor, 1973-1990, 1990-1994
Laspeyres Decomposition with 1990 as the Base Year

	2.4. EFFECTS 1973-1990							**2.5. EFFECTS** 1990-1994						
	Actual	Activity	Structure	Carbon Int	Energy Int	Fuel Mix	*GDP*	Actual	Activity	Structure	Carbon Int	Energy Int	Fuel Mix	*GDP*
Japan	3.7%	2.9%	1.0%	-0.5%	-0.4%	0.0%	3.7%	4.9%	2.3%	0.9%	1.7%	1.6%	0.0%	1.4%
Australia	2.8%	3.3%	-0.3%	-0.2%	-0.3%	0.0%	3.0%	2.1%	2.2%	1.3%	-0.7%	-0.8%	0.0%	3.3%
Denmark	1.2%	1.5%	-0.2%	-0.1%	-0.3%	0.1%	*1.3%*	1.2%	1.7%	0.0%	-0.5%	-0.5%	0.0%	*1.8%*
Sweden	1.8%	1.3%	-0.1%	0.4%	0.5%	0.0%	*1.9%*	-0.1%	-0.2%	0.1%	0.0%	0.0%	0.0%	*-0.6%*
W.Germany	2.8%	2.0%	0.2%	0.6%	0.6%	-0.1%	*2.2%*	0.0%	1.9%	0.2%	-2.2%	-2.0%	-0.2%	*1.8%*
UK	2.4%	2.7%	0.2%	-0.5%	-0.6%	0.0%	*2.0%*	-0.3%	0.0%	0.1%	-0.4%	-0.2%	-0.1%	*0.9%*
USA	0.5%	1.7%	0.0%	-1.4%	-1.4%	0.0%	*2.7%*	2.1%	1.9%	0.0%	0.2%	0.2%	0.0%	*2.3%*
Netherlands	2.2%	2.4%	0.2%	-0.5%	-0.7%	0.2%	*2.3%*	3.6%	2.4%	-0.1%	1.3%	0.0%	1.2%	*2.3%*

Note: The Netherlands from 1981, Denmark from 1972. Int. stands for intensity.

Fuel mix has almost no effect on our results. This is in part because the mix of fuels varies so little in CO_2 content. To be sure, increased use of diesel cars should reduce <u>intensities</u>, which should cause that factor to decline. Some of this has occurred in Germany and the Netherlands (as well as Italy and France, not examined in detail in this study). In all these countries, however, diesel is priced lower than gasoline. This advantage is utilised by those with greater than average yearly driving distances (Schipper and Lilliu 1999). And to some extent (Hivert 1996), those switching from gasoline to diesel increase their driving, consistent with the lower diesel price. Finally, marketing data show that for any given car model, a diesel version tends to have 10-15%

more power than its gasoline counterpart, to make up for the generally lower acceleration of a diesel engine. Thus only a small part of the potential economy of a diesel engine is actually realised as lower fuel use and CO_2 emissions in the countries where diesel cars are popular. This digression reminds us that ultimately we have to consider terms other than the modal energy intensity **I** alone in causing changes in emissions.

Since 1990, the picture of emissions is somewhat different. Since 1990, carbon intensity fell slightly in a few countries (W. Germany and Australia). But the decline from intensity changes in the U.S. has ceased. In all but two countries, the rate of growth in emissions, relative to GDP, after 1990 is higher than it was before 1990. And with recovery from recession, higher economic growth in many countries has stimulated both greater activity and slightly more rapid shift to cars and air travel. Thus since 1990, trends in emissions point away from their path before 1990.

2.6. Summary: More Motion, More Rapidly, Raised Emissions

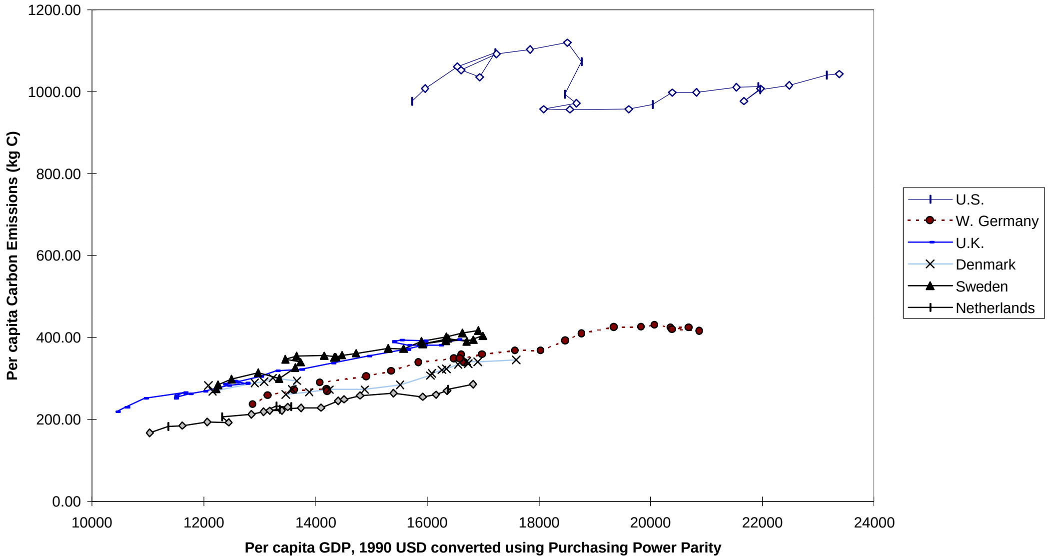
Changes in the amount people travel have been the dominant cause of rising emissions. Technical factors, as the vehicle and modal energy intensities represent, led to some restraint of emissions in a few cases for cars and trucks but only gave a net reduction in per capita emissions (for travel) in one country. Behaviour and system optimisation factors (i.e., modal choices and utilisation, speed), clearly boosted emissions as well. As of 1998, there was little sign that these factors alone were abating, although their coupling to ever-rising GDP may be weakening. Measures aimed at restraining CO_2 emissions from travel and freight should focus on the underlying factors driving emissions up since 1990, as these are likely the forces which policies must circumvent. In short, the challenge is not simply to reduce emissions from a static economy, but rather reverse important trends that are raising emissions. We turn to some of those forces next.

3 - THE CHALLENGES FACED: TRADITIONAL DRIVING FACTORS OF RISING INCOMES AND FUEL PRICES

Income (GDP) is an important factor driving travel activity and subsequent emissions. Only in the U.S. there appears to be some relenting or decoupling, both during the periods of the oil shocks (the bumps in emissions per capita at about USD 18 000 per capita GDP) and a slowing of growth after that period (Figure 8). There may be saturation approach in all countries, but emissions are still growing somewhat with incomes.

Fuel prices are also an important determinant of fuel consumption in the long run, as a wide range of studies has shown (reviewed in Johansson and Schipper 1997)[12]. But real fuel prices were only high in any given country for a relatively brief period, 1974-1977 and 1979-1986. In many European countries today they barely keep up with inflation, while in the U.S. they are at historic lows. With modest declines in fuel intensity in Europe and a 30% reduction in the U.S. today vis à vis 1973, the incentive to respond to costs is small both for vehicle makers and for buyers or users. What can be done to restrain the growth in emissions in Figure 8?

Figure 8: Per Capita GDP and Per Capita Carbon Emissions from Travel Sector



Source: LBNL and IEA

Factors causing changes in CO_2 emission are intimately related to the nature of transportation – comfort, convenience and speed. Those factors driving distance as well as modal choice are related to individual and societal choices about housing, work and leisure location. The same is true for freight. But the cost of fuel is but a small fraction of the total cost of either travel or freight, even before the cost of the transport infrastructure is considered. And the choices noted here are deeply rooted in a transportation context. This means that these choices – today's slowly evolving transportation patterns – may be difficult to stop simply because of CO_2 concerns. Put another way, even a stiff carbon tax would still leave the price of road fuels relatively unchanged in most countries because they are already heavily taxed. Drivers face many other costs besides those that might reflect carbon concerns. To be sure, natural limits (saturation of distance or time of travel, potential saturation of the distance physical goods are sent around) or local constraints (congestion, parking problems, local pollution) may slow or reverse some of these trends. But most national transport plans still foresee increases in personal and goods transportation with GDP without policy intervention.

4 - THE FUTURE

What could restrain CO_2 emissions in the future? In the closing section of this review, we discuss what our research suggests. Recall the ASIF formulation (Activity, Structure, Intensity, Fuel Mix) presented in the beginning. The I and F terms are strongly influenced by technology, although there are many behavioural components of I, too. A is clearly coupled to incomes, and S tends to shift towards more carbon-intensive modes as incomes grow. Governments in Europe therefore place their hopes on the multiplying effects of changes in all these components to reduce growth in emissions and eventually turn them back down.

4.1. Technology: Mainly I and F

There is no doubt that technology offers enormous potential for reducing CO_2 or other emissions (and many other externalities), at modest cost, if asked to play a role (Michaelis et al. 1996; Peake 1997; IEA 1997c, IEA 1999). This was reinforced by the flurry of announcements around the time of the Kyoto conference, such as Toyota's marketing of the Prius Hybrid in Japan, and soon in the United States, with Europeans close behind. The recent voluntary agreements (VA) concluded between the European Union and the European Automobile Manufactures' Association ACEA promises that new cars on average will emit 25% less carbon per kilometre by 2008 than in the mid 1990s. For Japan a 23% reduction by 2010 for gasoline cars (15% for diesel cars by 2005) is foreseen as part of the new "Top Runners Programme" announced in December 1998. In the U.S. there is no goal, but an aggressive research programme (Partnership for a New Generation of Vehicles, or PNGV) may produce technologies that can reduce fuel use more than the current wave of large sport-utility vehicles is raising fuel consumption. In all countries, some combination of advanced gasoline engines and advanced diesels (which offer fuel economy as low as 3-5 l/100 km), and restraint or even reversal in the growth of car power, weight and options, could make these changes a reality. The more the latter grow, the more technology has to be applied to offset their upward pull on emissions. Thus technology is fighting an uphill battle.

In the longer term, when advanced technology being developed in the U.S. (PNGV), Japan (hybrids), or Europe (fuel cells, hybrids) could reduce emissions even more. But all these technological strategies require time. If new cars average 25% less carbon emissions in 2002 than they did in 1995, this means approximately 20% less emissions in real traffic. That in turn means that around 2020, all cars on the road will have been built after 2002. But it is not likely that the total volume of car use will have stagnated; rather it will grow more than 20%. Hence the VA is only a start, and must not represent a point of stagnation if emissions are even to be levelled. A 40-60% cut in test fuel consumption of new cars by 2015 could send their emissions below the 1990 level by 2035. Thus technology – and policy-makers – must be patient. While even greater cuts are discussed at seminars on “hypercars” (Lovins and Barnett 1993), they still have not appeared in parking lots, show rooms, or on motorways.

One revolutionary change may be in sight. The marketing strategies of Daimler Benz and VW include advanced small cars. The Daimler “A” is every bit a Mercedes but is a small four-passenger car, while it’s spin-off “Smart” is a very small two-passenger vehicle. VW will offer a very advanced diesel and light body framework called the Lupo with projected consumption of 3 L/100 km. These developments represent both a gamble and a recognition of three realities: that very fuel-efficient cars with very clean emissions may soon have priority in cities (particularly in Europe and the developing countries); that the second family car market in Europe is now maturing, which could imply a market for small cars; and that the small “smart” car may well offer the first step for an affordable and <u>acceptable</u> car for most of the developing countries. Perhaps the “smart” car, as well as various versions of hypercars, will provide clean, sustainable mobility for the Third World?

4.2. The Role of Behaviour: Mainly A and S

The ASIF formulation shows the influence of behaviour on total emissions. Indeed, even the brief review of trends given here (and developed more fully in Schipper and Lilliu 1999) makes it clear that differences in total travel per capita and modal share contributed more to overall differences in emissions per capita than differences in fuel economy. But the decomposition of trends showed that behaviour, driven principally by rising incomes, supports more travel and more reliance on carbon-intensive modes.

Carbon concerns alone are unlikely to reverse this slow trend. Changes in fuel prices alone may lead to significant changes in vehicle or fuel technology, but not large changes in travel behaviour. And the examples given immediately above make it clear that behaviour starts with the choice of the vehicle. No authority is actively telling its citizens to abandon cars or stay home. But changes in the European policy landscape motivated by the transportation concerns we sketched in the introduction may have an important impact on emissions by restraining growth in A and by pushing S somewhat back towards modes with lower carbon intensity. These changes could affect basic costs of using vehicles beyond fuel alone. How hard can these policies push? Certainly speed limit enforcement, driver training, labelling of fuel economy, and other measures could help. These kinds of measures push behaviour to use technology in a fuel-saving way, an important interaction for policy-makers to consider.

4.3. Policies to Push

In our new book, we review the strategies of six IEA countries. Four are soundly based in overall transport reform, and two (Denmark and Sweden) rest principally on the idea that each mode of transport should bear its full external social costs. In each strategy a combination of technological change (including that driven by research, development, and demonstration projects and pricing policies), higher costs for lower-emitting fuels, and application of transportation costing and regulatory measures could both improve transportation efficiency and restrain or even reduce CO_2 emissions over the next three decades. These could change <u>both</u> emissions per km <u>and</u> total km enough to make a real break in travel fuel consumption, as clearly happened in the U.S. in the 1970s and 1980s. CO_2 policies alone – or technologies aimed at CO_2 alone – may not have a great enough impact on emissions to reduce them without dramatic technological breakthroughs that appear quickly in the marketplace. But CO_2 measures implemented in transport policy measures could leave European, Japanese, and N. American transportation systems with lower total CO_2 emissions in the second or third decade of the next century than at present.

If the "sins" of transport are indeed as serious as the literature suggests, then their prompt and thoughtful treatment, together with measures designed to address CO_2, including taxation, could break the links shown in the opening figures. And if governments are really as concerned both about "sustainable transport" and CO_2 emissions as their prolific reports suggest, then the forces could be mustered for this important integration. Indeed, recent national CO_2/transport policies for Germany (UM 1991 and subsequent modifications), the U.K. (DETR 1998), the European Union (CEC 1995a) the Netherlands (VROM 1996b and subsequent modifications), Denmark (Trafikministeriet 1997), Sweden (KOMKOM 1997), see ECMT 1997 for a review) make it clear that at least in Europe, governments have linked transport CO_2 to the wider problems of transportation, rather than isolated the CO_2 problem on its own. Many of these considerations are contained in the EU White Paper "Fair and Efficient Pricing of Transportation" (EC 1996). This is also a course discussed in the recent US NAS study (NRC 1997), but so far, there has been no integrated transport/CO_2 policy appearing from that country.

Will any of these efforts succeed? The British effort is spearheaded by local planning and steady fuel price rises; Dutch, German, Danish and Swedish authorities have introduced differentiated taxes on existing (and in some cases) new vehicles to reflect criteria emissions (i.e., CO, NO_x, and HC) and indirectly CO_2, and the Danish Government has imposed yearly auto registration fees that rise with the original test fuel consumption of each vehicle when new above a given balance point (Skatteministeriet 1996; Trafikministeriet 1997). Directly or indirectly, all these European authorities have discussed some kind of road pricing, but for which vehicles, and whether local and/or long-distance is unclear. The French have already introduced peak-time tolls on their autoroutes. All countries talk about raising the competitiveness of rail through privatisation, infrastructure improvements or other means, and all countries will promote better local collective options. But no one in any country can more than guess what will be the ultimate package of measures, how fuel taxes will change, and how behaviour will change.

One characteristic of every package that survived to 1999 is that it was watered down or stretched out in time from what was originally envisioned, a recognition of the political difficulties of moving quickly with transportation policy. Indeed, most governments now openly admit that they will not meet the transport sector's Kyoto goal by 2020. But present forces in place do seem to assure that emissions will be somewhat lower than otherwise, with a gap growing to as much as 25% by 2025. Thus Europe and Japan are off to a start.

4.4. Policy Implications of Our Findings

European countries and Japan have started to confront CO_2 emissions from travel in the context of overall transport reform. Their efforts will cause measurable change, but not as much as Kyoto goals imply. We summarise below what our work implies for the structure of future policies.

Present trends in motorization and mobility of goods and people in wealthy OECD countries are still raising fuel use and CO_2 emissions at nearly the rate of economic growth. While there are some signs of saturation in the wealthiest countries, there is almost no break in car use, car size/features, or resulting CO_2 emissions. Nevertheless, countries will have to take stronger steps towards restraint in CO_2 emissions if they want greater results in the long run.

CO_2 policies must be embedded in larger transport reform measures, as noted at the outset and codified now in the CO_2 plans of a number of European countries. Most of the measures designed to reform transport and make the system more effective will lead to somewhat lower levels of traffic, a modest rise in the role of collective modes, and less air pollution. These all help restrain CO_2. Within this setting, CO_2 -specific measures strike hardest and show the greatest welfare benefits as well.

Pricing is seen in Europe as key to rearranging the various signals that affect the use of cars over other modes, the fuel economy of cars, and the choice of fuels. No one expects price reforms alone to solve problems, but few expect transport problems to solve themselves without pricing reforms. This is particularly important for the possible trade-offs among pollutants, the search for fuels with lower carbon content, and the encouragement of low-pollution vehicles.

Technology offers enormous potential for reducing environmental problems associated with transport. But technology depends on human behaviour for acceptance and proper deployment. Proper carbon pricing is also central to both developing and deploying technology. Car companies fear large investments in fuel-saving technology or alternative propulsion without strong market support for the purchases of what they develop. Subsidies for so-called "clean" alternatives will have little effect unless the "dirty" status quo is clearly marked with taxation. Even with a dramatic breakthrough in hypercars that reduces fuel consumption spectacularly, taxation reform will be necessary just to keep revenues about constant for maintaining the transport infrastructure. And while very low-consuming vehicles do not necessarily imply significant increases in vehicle use, wise governments will act to make sure that when technology leaps, signals about both CO_2 and other transportation externalities are not muted.

There are many local policies (not explicitly reviewed here) that take direct aim at daily mobility, such as road pricing and other forms of transport demand management. Introducing such schemes is important for clearing congestion, but is often politically difficult. Similarly, there is some expectation that careful attention to land use planning and higher density development will reduce the need to travel. The positive experience with land use planning in Nordic countries and the Netherlands is hard to relate to specific declines in car use or drops in total mobility. These tools may be wise transport planning instruments to keep cities pleasant, but they remain uncertain tools for reducing CO_2 emissions unless employed in conjunction with other measures.

5 - WHAT IS HOLDING THINGS BACK?

What factors hinder changes in the transport system that would reduce or restrain CO_2 emissions? Clearly the price of emitting CO_2 continues to fall for most societies, and that alone is a hindrance. Incomes are rising, which makes larger cars and more car (and air) travel affordable for more people. To this must be added expected resistance by political and business groups, as well as individual consumers, to policies that at least in the short run will redefine costs associated with travel. Those who know their costs will likely rise are well informed and on guard.

But there are other inhibiting factors. For one thing, the motor vehicle business itself is under pressure from within (over-capacity and competition, labour strife), from regulators (clean air, fuel economy, uncertain incentives), and above all from consumers, whose future car-buying and using habits are always unclear. These problems make the vehicle manufacturers naturally conservative.

Finally, the scientific consensus over CO_2 does not translate easily into a social imperative felt by every driver. Lacking a serious drive to reduce or restrain CO_2, one cannot expect every actor in the chains we have portrayed to be focused on CO_2 restraint. That is why we argued that the most important step for CO_2 policies is to align them with those addressing more immediate transport-related problems, problems for which strong constituencies are pushing for real solutions.

Let this appear to be yet another call for "no regrets policies" and let it be clearly acknowledged that a wide range of groups oppose changes in regulations and pricing in every country trying to do so. But if it is successful, steps towards transport reform likely will lead in their own to restraint in CO_2 emissions. These steps could provide valuable time for robust low-CO_2 vehicles and fuels to truly cut emissions in mobile countries and significantly limit the rise in CO_2 emissions in other countries. Such policies could also lead to a truly sustainable transport system, where users pay their own way and no damage or net cost is left for future generations to deal with. If lifestyle changes that usher in saturation of mobility of goods and service further reduce the growth in transportation activity relative to incomes, restraining CO_2 emissions could be even more successful than thought. Our grandchildren will probably breathe more easily, and be cooler as well.

6 - ENDNOTES

1. See Kaageson, 1993; COWI, 1993; OECD, 1995; CEC, 1995a; COWI, 1995a, 1995b; Dept. of Transport, 1996; Pearce et al., 1996; Det Oekonomiske Raad, 1996, Delucchi, 1997, ECMT 1998.
2. Houghton, 1994; CEC, 1995b; UM, 1991a; UM 1991b; VROM, 1996a, 1996b; KOMKOM, 1997; US NRC, 1997; Trafik Ministeriet, 1997.
3. Concerning decomposition in other sectors, see Schipper 1995; Schipper, Figueroa, Price, and Espey, 1993; Schipper, Steiner, Figueroa, and Dolan, 1993.
4. See for example Schipper, Steiner, Duerr, An, and Stroem, 1992; Schipper et al., 1996; Scholl, Schipper and Kiang, 1996; Schipper, Scholl and Price, 1997.
5. A main case for using Laspeyres indices is their simplicity of calculations. However, note that Laspeyres indices often leave large residuals.
6. See Schipper, Gorham, and Figueroa 1995.
7. These figures are assembled from national data (IEA 1997a) and count the energy content of each kind of fuel, which is higher for diesel than for gasoline or LPG. Results are then converted to "gasoline equivalents" at the lower heat content of gasoline of 31.4 mJ/litre.
8. See Schipper, 1995; Scholl, Schipper and Kiang, 1996.
9. For Denmark the falling automobile factor led to increased emissions. We used this falling factor based on our interpretation of a number of national travel surveys. Consequently our results differ from the load factors used by Vejdirektorat, the National Road Authority.
10. See Johansson and Schipper, 1997.
11. We are ignoring full fuel cycle emissions, i.e., emissions associated with producing, refining, and transporting fuels.
12. See Johansson and Schipper 1997 or Thompson, Fraser and Swaminathan 1995.

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