Economics of Transport and Environment – Basics 2

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Summer school EAERE - Venice 2009

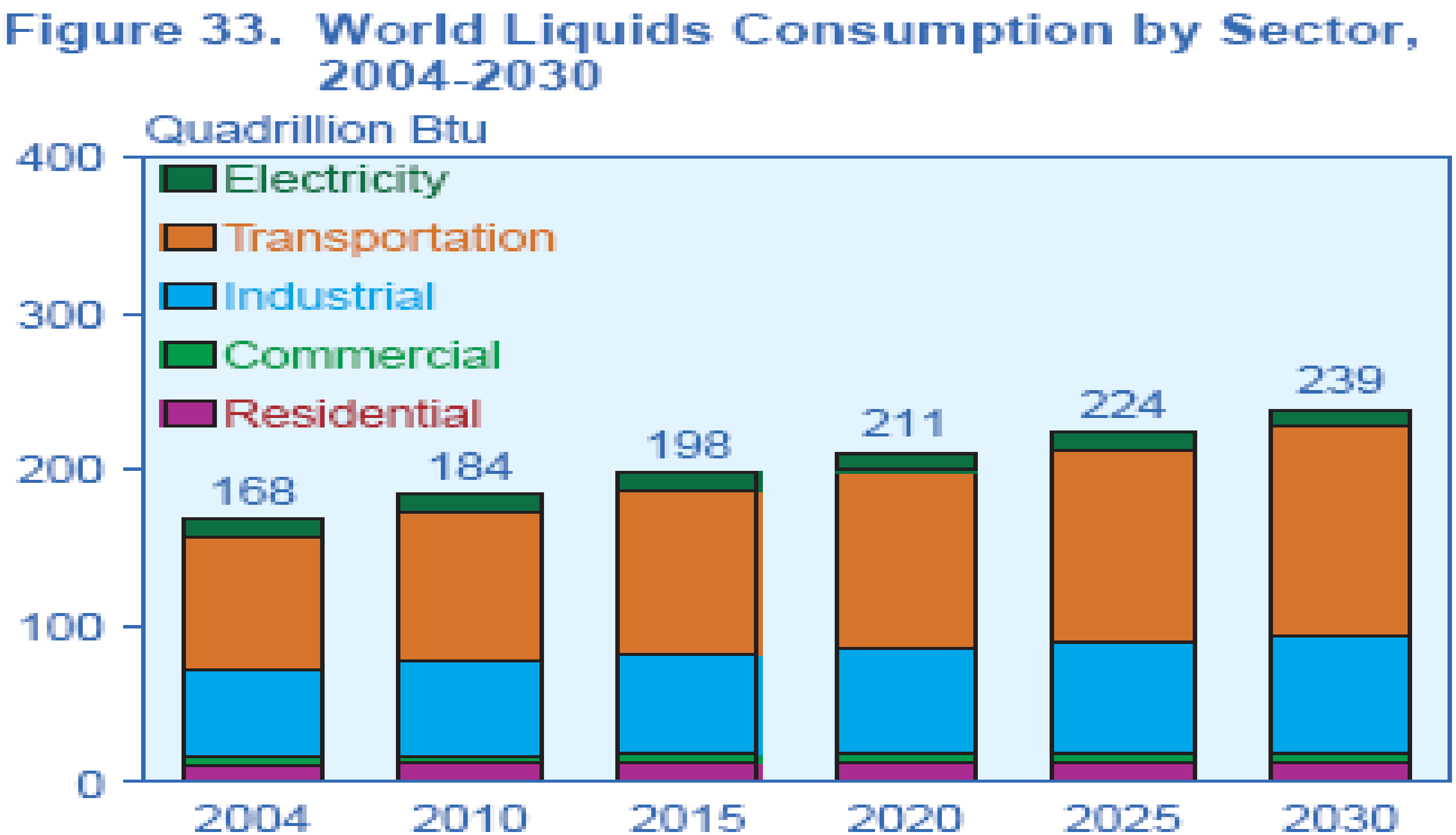
Outline

- **Some facts and trends**
- The many questions: Climate change, other air pollution, congestion, accidents, noise etc.
- Towards a comprehensive approach
- Do we need more fuel efficient cars?
- Short term fuel choice issues
- Long term fuel choice issues
- Accident externalities - debate

Some facts and trends I

- Increasing energy use in transport sector: mainly oil due to:
  - Low substitution possibilities
  - Increasing car ownership (income elastic demand for new industrialising countries) – in 15 to 20 years car ownership will have doubled

Transport sector: mainly oil and increasing as there are not many alternatives



Sources: 2004: Derived from Energy Information Administration (EIA), *International Energy Annual 2004* (May-July 2006), web site www.eia.doe.gov/iea. Projections: EIA, System for the Analysis of Global Energy Markets (2007).

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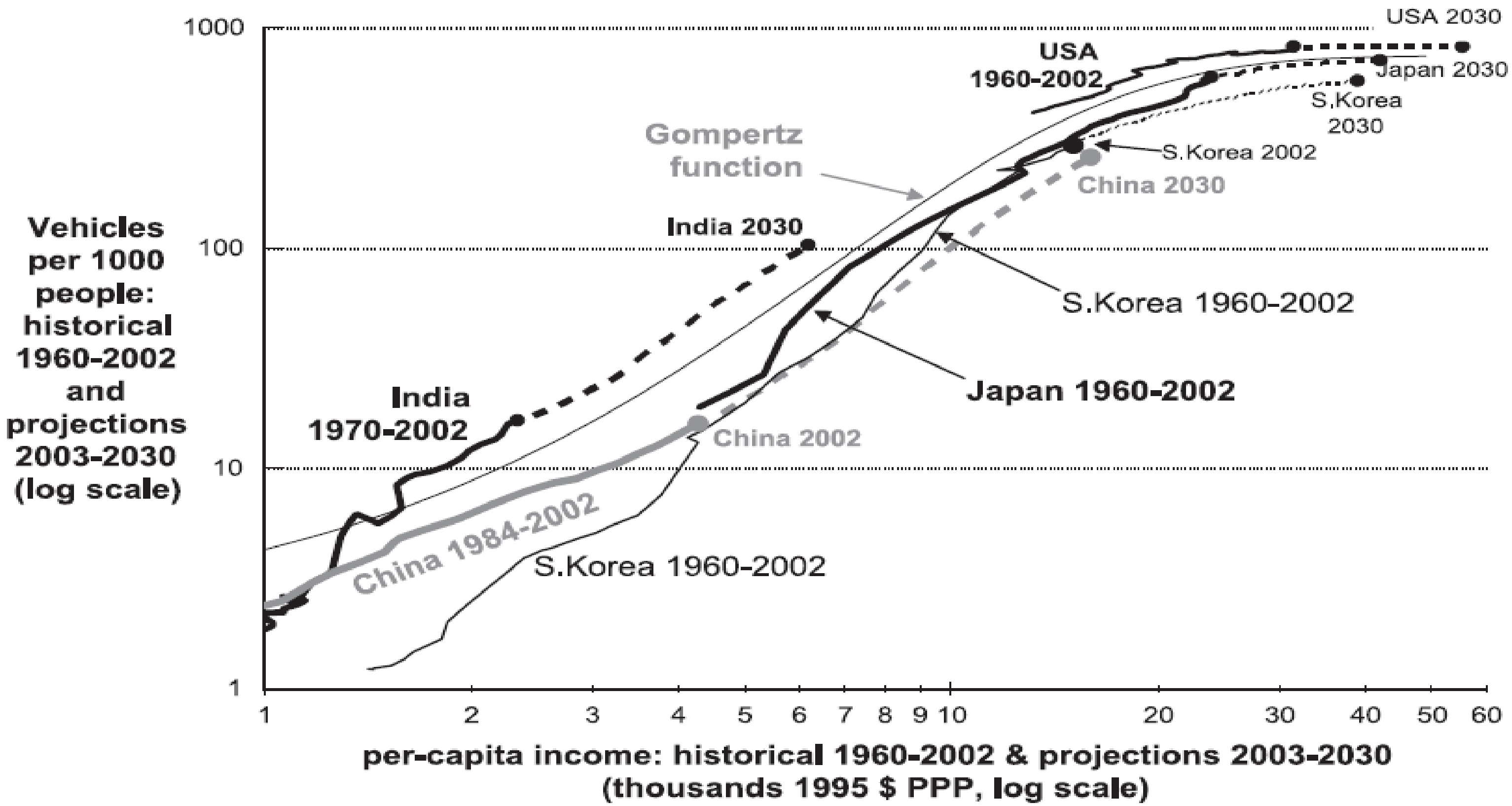
Car ownership I

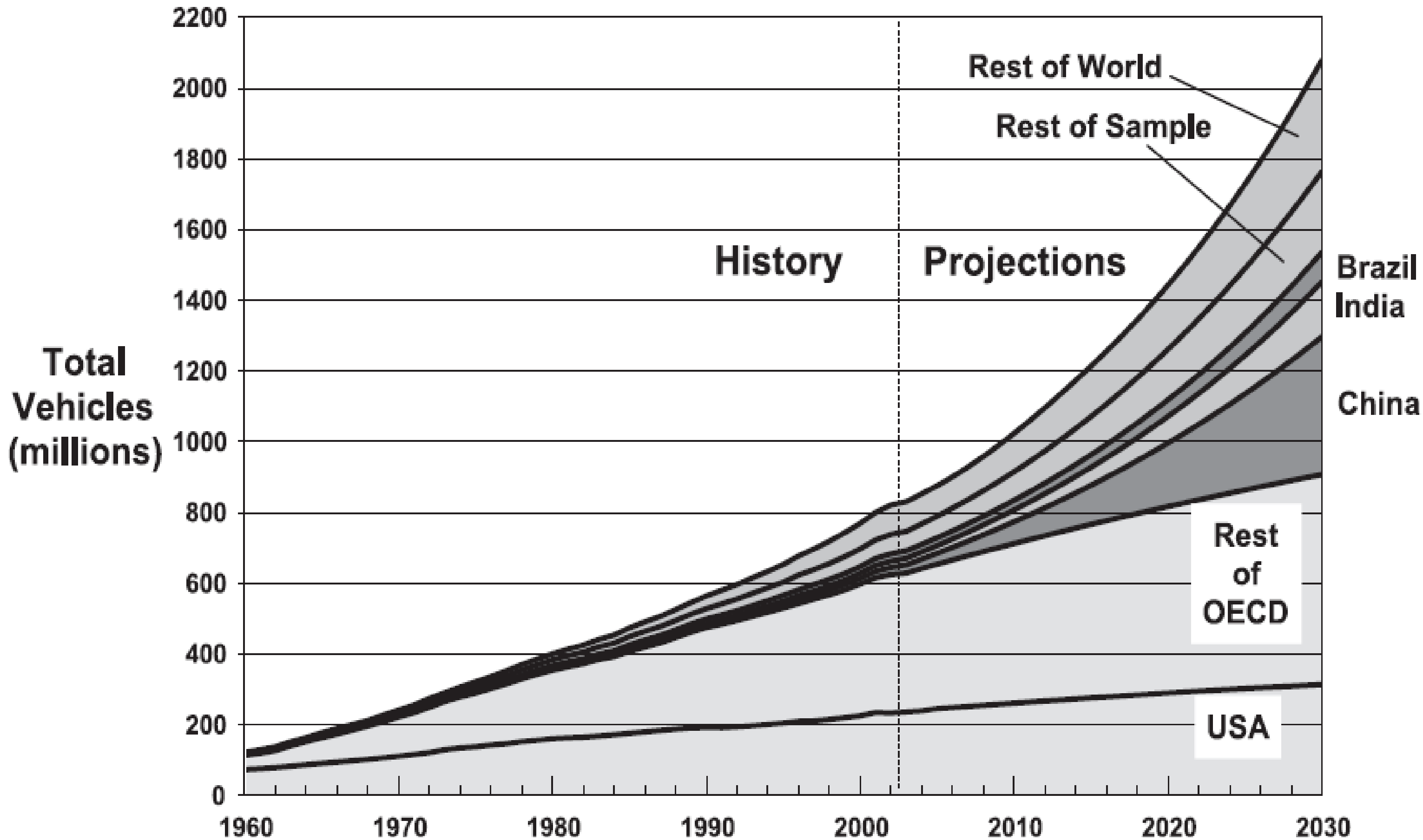
(source:Dargay, Gately, Sommer EJ 2007)

Figure 9. Historical and Projected Growth for China, India, South Korea Japan and USA: 1960-2030



Car ownership in future II (source:Dargay, Gately, Sommer EJ)

Figure 10. Total Vehicles, 1960-2030

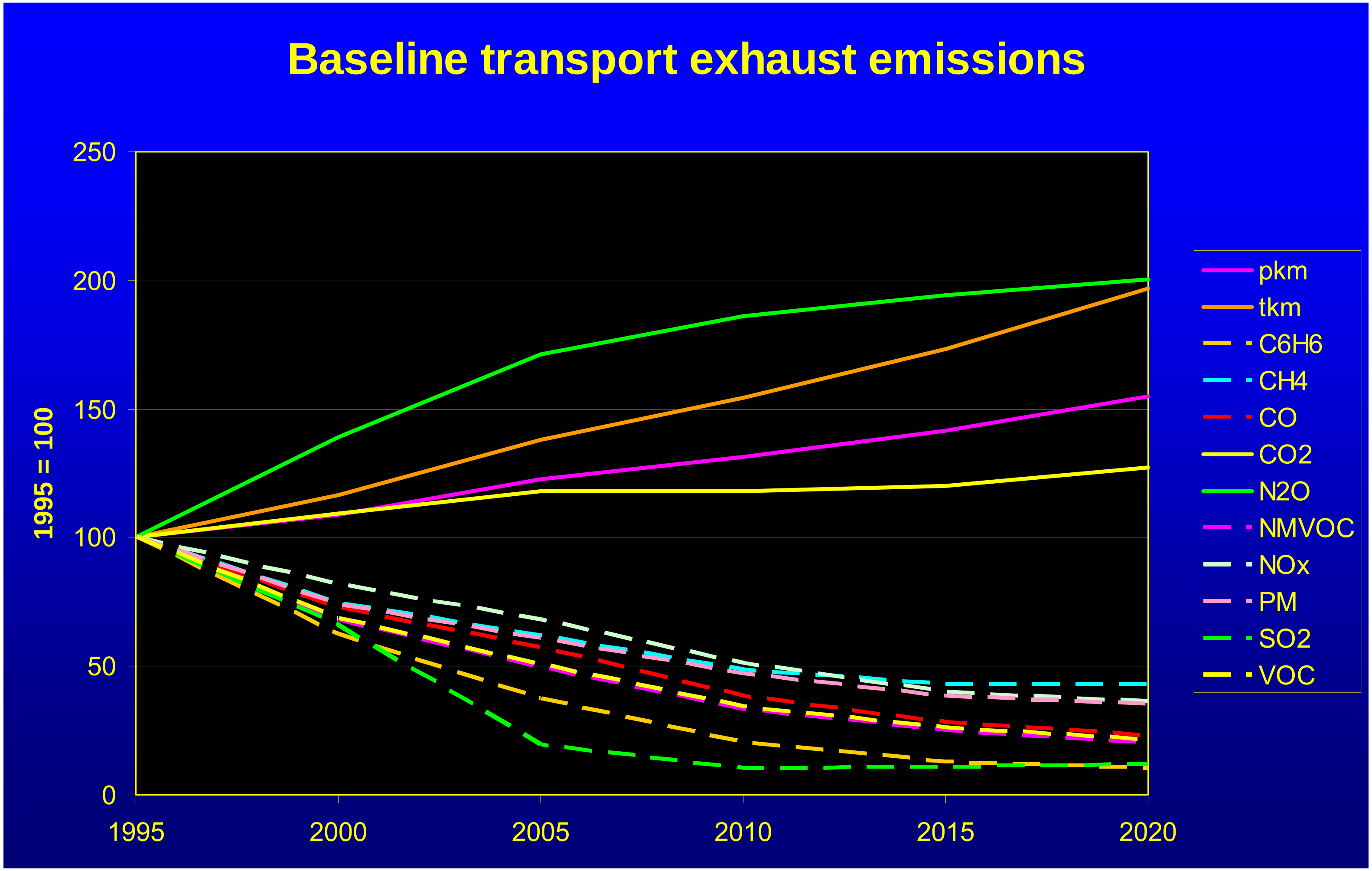


Some facts and trends II

- Increasing energy use in transport sector: mainly oil
- Conventional emissions of transport have strongly decreased
  - Successfull technological fix: catalytic converter + cleaner fuels that take out >90% of most pollutants
  - No reduction of emissions of CO_2 in transport sector
  - Source: TREMOVE II (partial equilibrium model of transport sector for all EU countries constructed to discuss transport pricing and emission regulation – see www.tremove.org

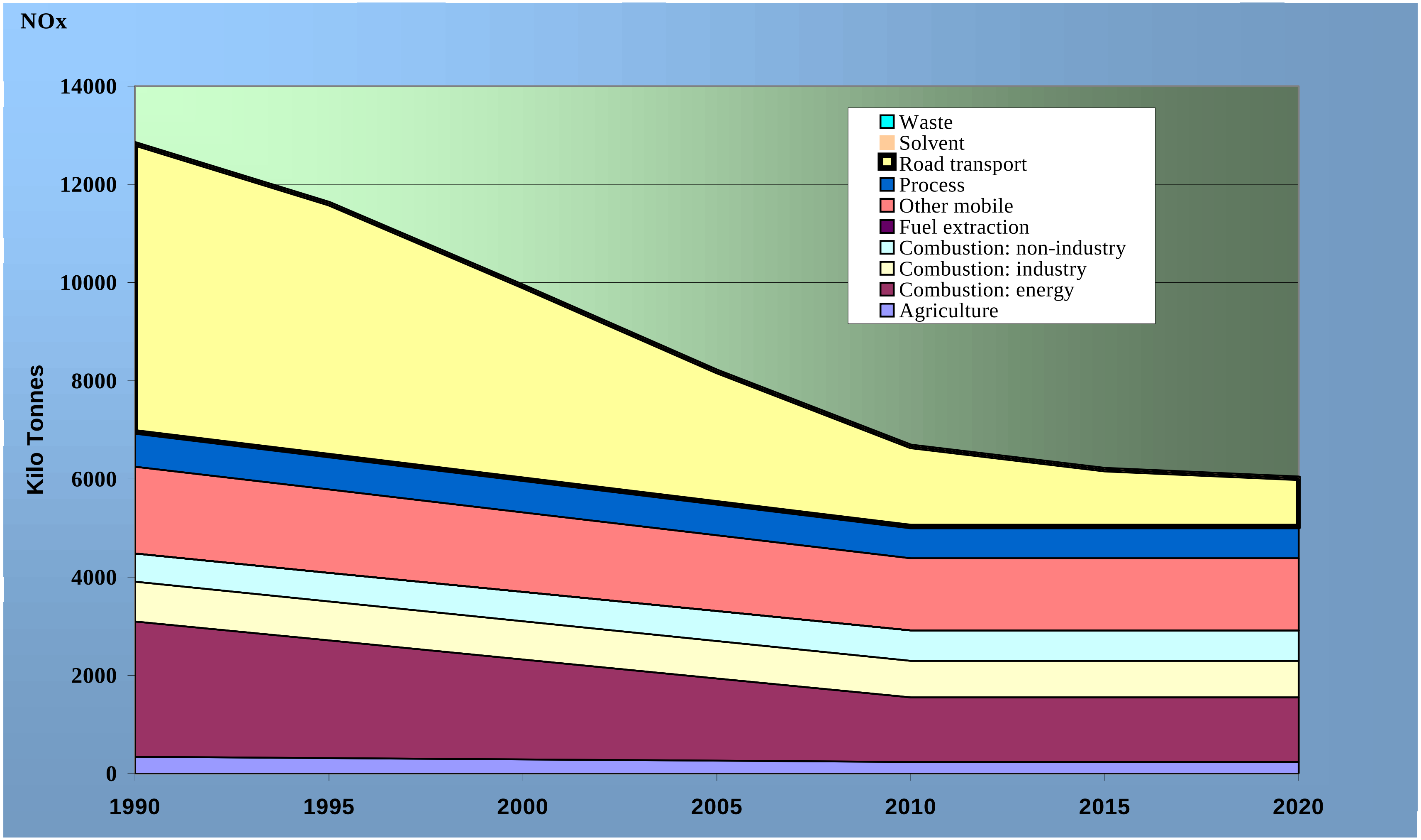
TRANSPORT EU Activity and emissions –

strong decrease emissions except CO2 (source:TREMOVE II)



NOx EMISSIONS: TRANSPORT vs REST

yellow is transport – kTONS from 1990 to 2020 –(source: TREMOVE II)



Simplest model for car market

(see Calthrop & Proost, 2003)

- 1 period model
- Perfectly competitive car market
- No congestion
- Constant air pollution damage d per unit of car use if no abatement
- Marginal Benefit of car use = 1-x (where x is car use)
- No resource cost of car use
- Pollution control per unit of car use z
  - with total abatement cost of $(c/2)z^2$, we chose c=1
  - Marginal abatement cost = z so is linear in z
- Total Pollution damage = x d (1-z)

Note: Simplest model

- Optimal solution for a central benevolent planner (1st best)

$$\max \int_0^y (1 - x - d(1-z) - 0.5z^2)dx$$

$$w.r.t.\ \ z, y$$

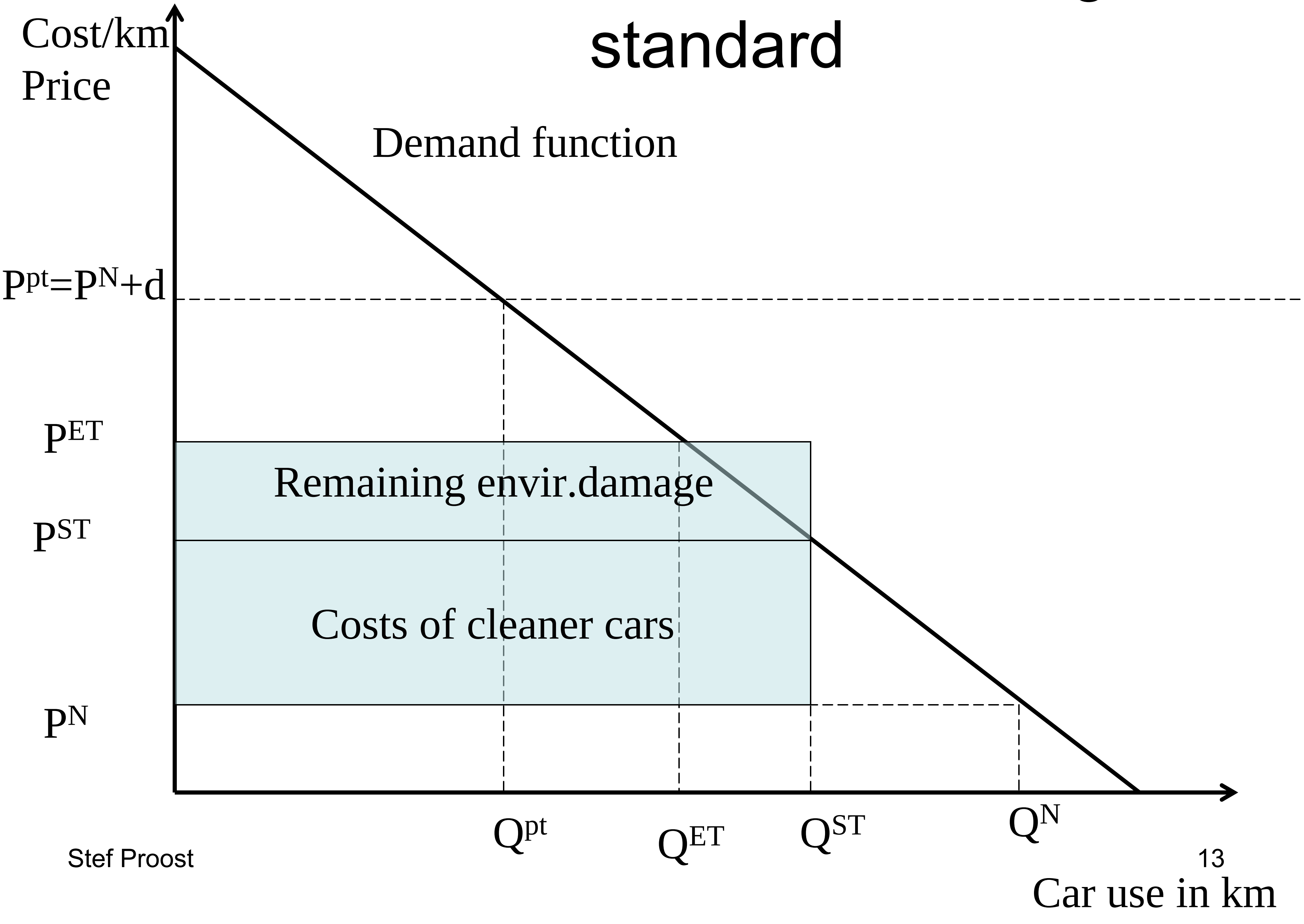
$$y: \quad y = 1 - d(1-z) - 0.5z^2$$

$$z: \quad z = d$$

Note: Simplest model 3

- Optimal level of pollution control is achieved when
  - MC of abatement z = marginal benefit (d)
- optimal use of cars is reached when marginal benefit of car use (1-y) equals the remaining optimal marginal damage d(1-d) plus the optimal marginal pollution abatement cost $0.5d^2$
  - So we have $y^{opt} = 1-d(1-0.5d)$
  - This means that the optimal car use depends on the air pollution damage and on the optimal implementation or not of abatement measures

Car market model – technological standard



Instruments compared for EURO4 standard

for non CO2- Relative to Emission tax (=100)

	‘d=0.05	‘d=0.1	‘d=0.15
Emission reduction Subsidy	93	89	61
Km tax	11	11	10
Tech Standard	97	99	99

Note: Comparison of instruments

- Comparison basis: c=0.11 so that for d=0.1, we have optimal z= 0.9 and this corresponds to the effect of standard Euro4 compared to Euro 1(approx 90% reduction of conventional emissions)
- So abatement was relatively cheap and a techn standard is rather performant and product tax does very badly
- If more heterogeneity in cars (age, different technologies), the emission tax will do relatively better than a standard

Some facts and trends III

- Increasing energy use in transport sector: mainly oil
- Conventional emissions of transport have strongly decreased
- Transport modes
  - Passengers: cars dominate with more then 80 to 90%, air transport is growing quickly
  - Freight: mainly trucks, waterborne transport for intercontinental transport and on some routes
  - Data for EU and intercontinental comparisons: see http://ec.europa.eu/transport/publications/statistics/statistics_en.htm)

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Transport and environment Policy problems

- "Environment and resource" problems in transport sector
  - Fossil fuel consumption and greenhouse gas debate
    - » transport is responsible for some 25 to 30% of GHG emissions
  - Fossil fuel consumption, short term disruptions and long term resource availability
    - » Road and air transport are very dependent on oil products, can we accept this?
  - Traditional air pollution from transport
    - » CO, NOx, VOC,Particles
  - Noise
- "Other" problems in transport sector
  - Congestion
    - » In most high density areas road (and rail) capacity is too small in peak causing schedule delay and queuing
  - Traffic accidents
    - » Traffic accident risk is decreasing but is still experienced as much too high
  - Wear and tear of infrastructure use
    - » Every truck damages road surface and this reduces road quality for others
  - Parking
    - » Often rationed inefficiently, "cruising for parking"

Pick your “Solution”

- Better fuel efficiency
- Better fuels
- Abatement technologies for cars
- Car sharing
- Modal switch (take the train or the bus)
- Suppress trips
- Build more roads
- Relocate activities –land use planning –

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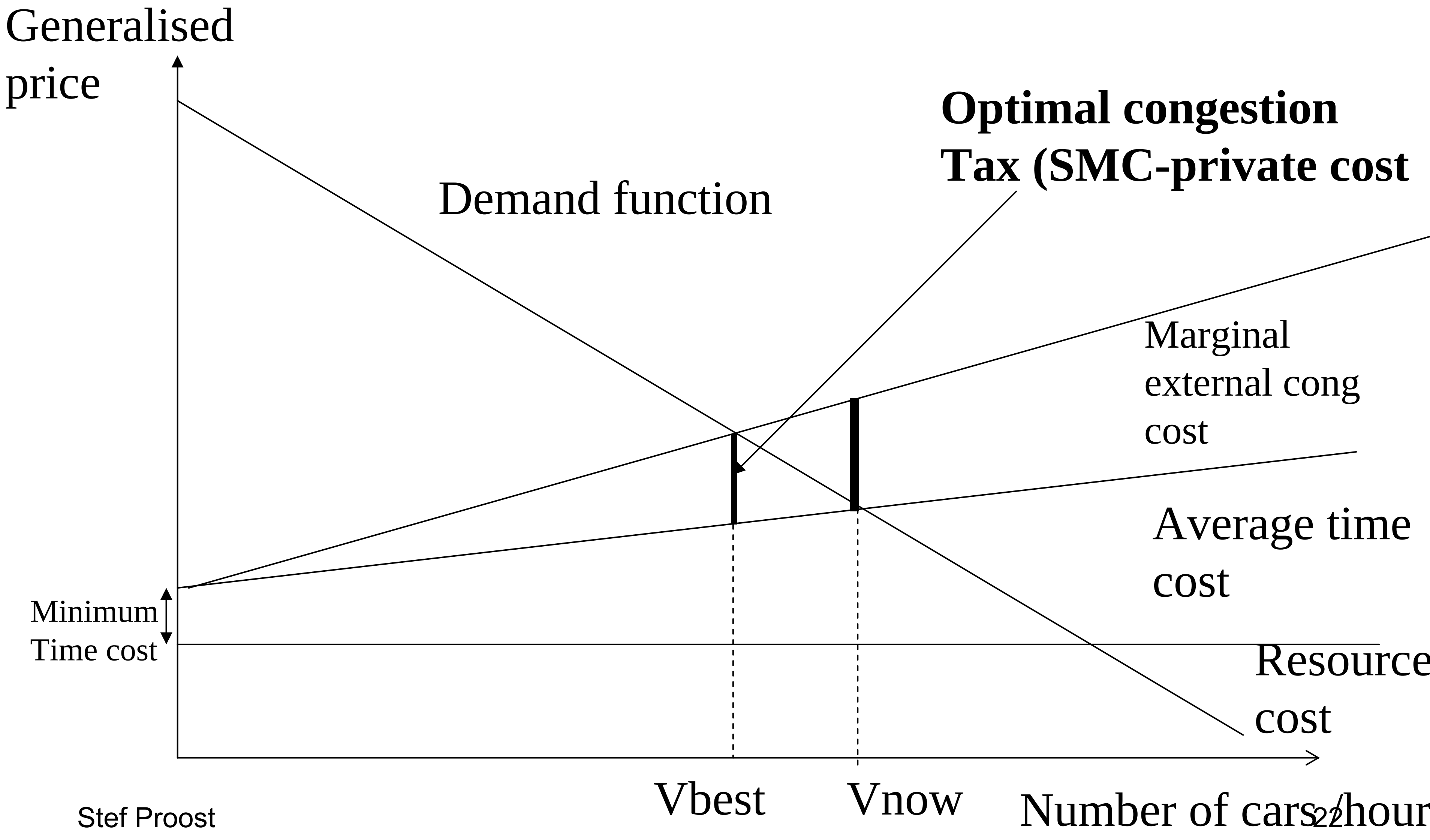
Simplest congestion model for road transport market “Average time cost model”

- Distinguish different subperiods within the day
  - Peak, shoulder, off peak
- Average Time cost (or speed flow) function that gives Time per km as function of volume/capacity
- Demand functions for every subperiod and cross price elasticities (substitution within the day and with other modes) in function of “generalised cost”
  - Generalised cost= money cost+time cost

Road Transport market and Congestion costs

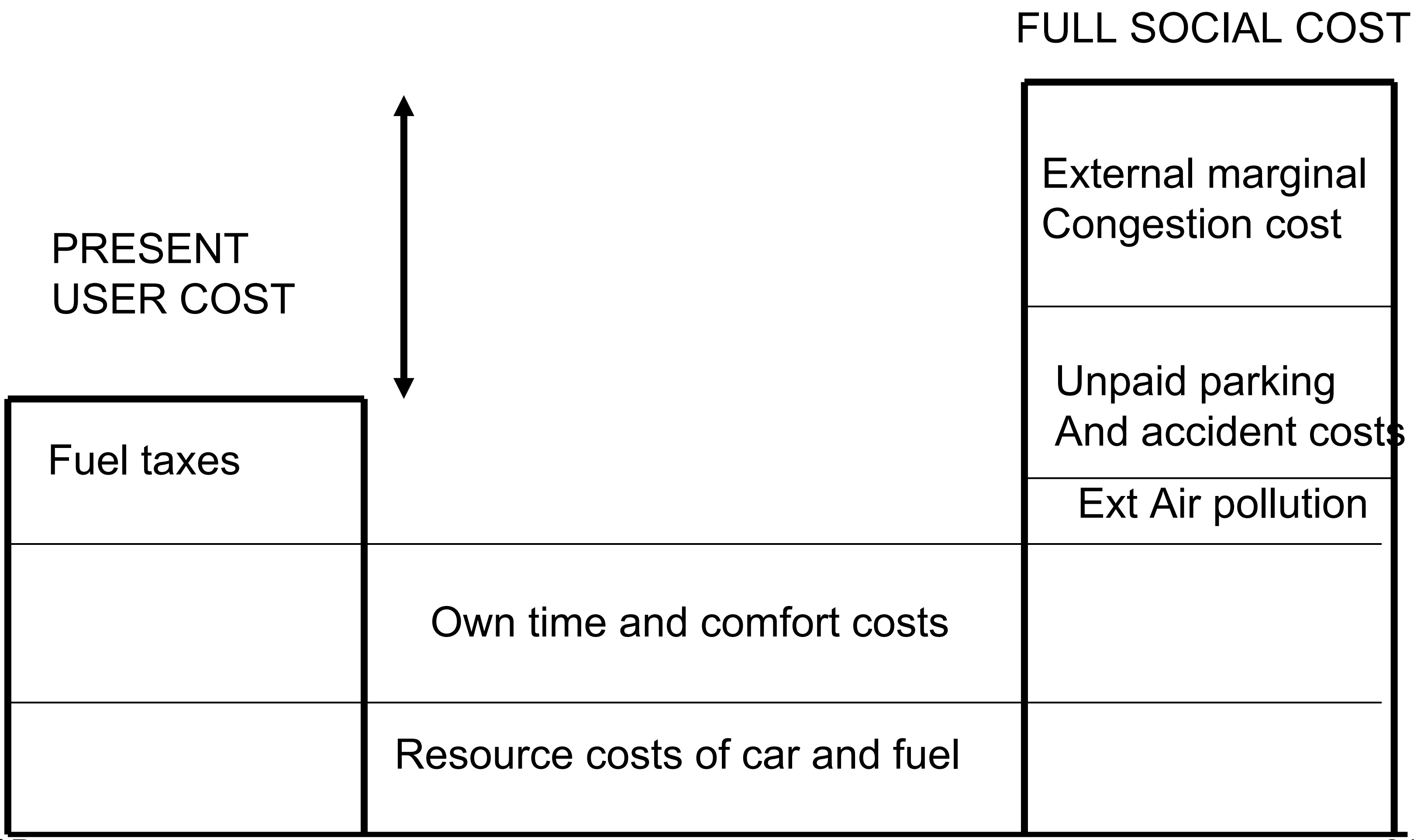


Note: Simple Analytical example of average time model

- Assume that average time cost T (for a trip) is linear function of flow V in peak say T=a+bV
- Total time costs $VT=aV+bV^2$
- Marginal congestion cost (total increase of time costs when one user extra)

$$\frac{\delta VT}{\delta V} = \frac{\delta(aV + 2bV^2)}{\delta V} = a + 2bV$$

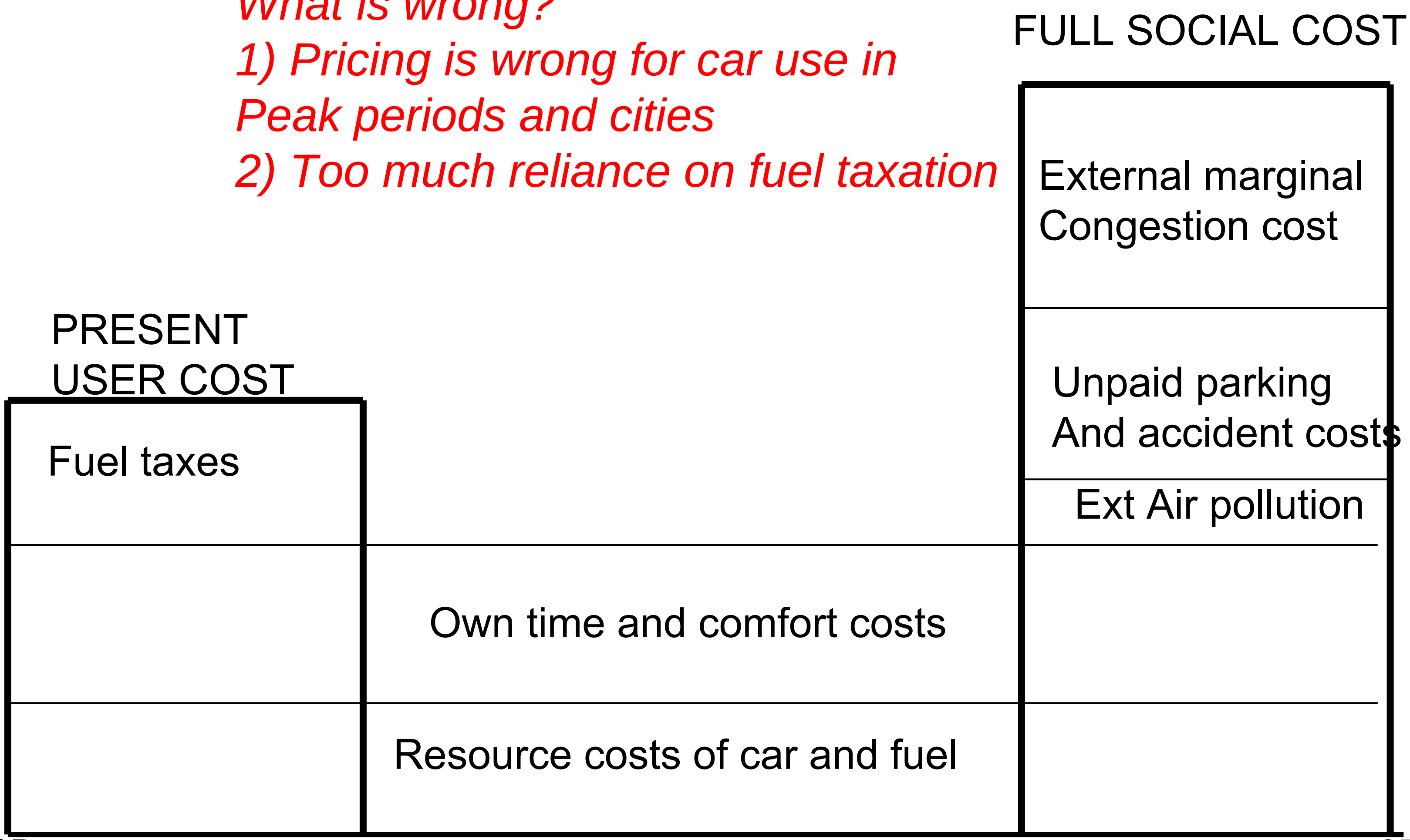
Present taxes and full costs (EU-not US)
example of a small car in the peak period



Present taxes and full costs

example of a small car in the peak period

What is wrong?
1) Pricing is wrong for car use in Peak periods and cities
2) Too much reliance on fuel taxation



Present taxes and full costs
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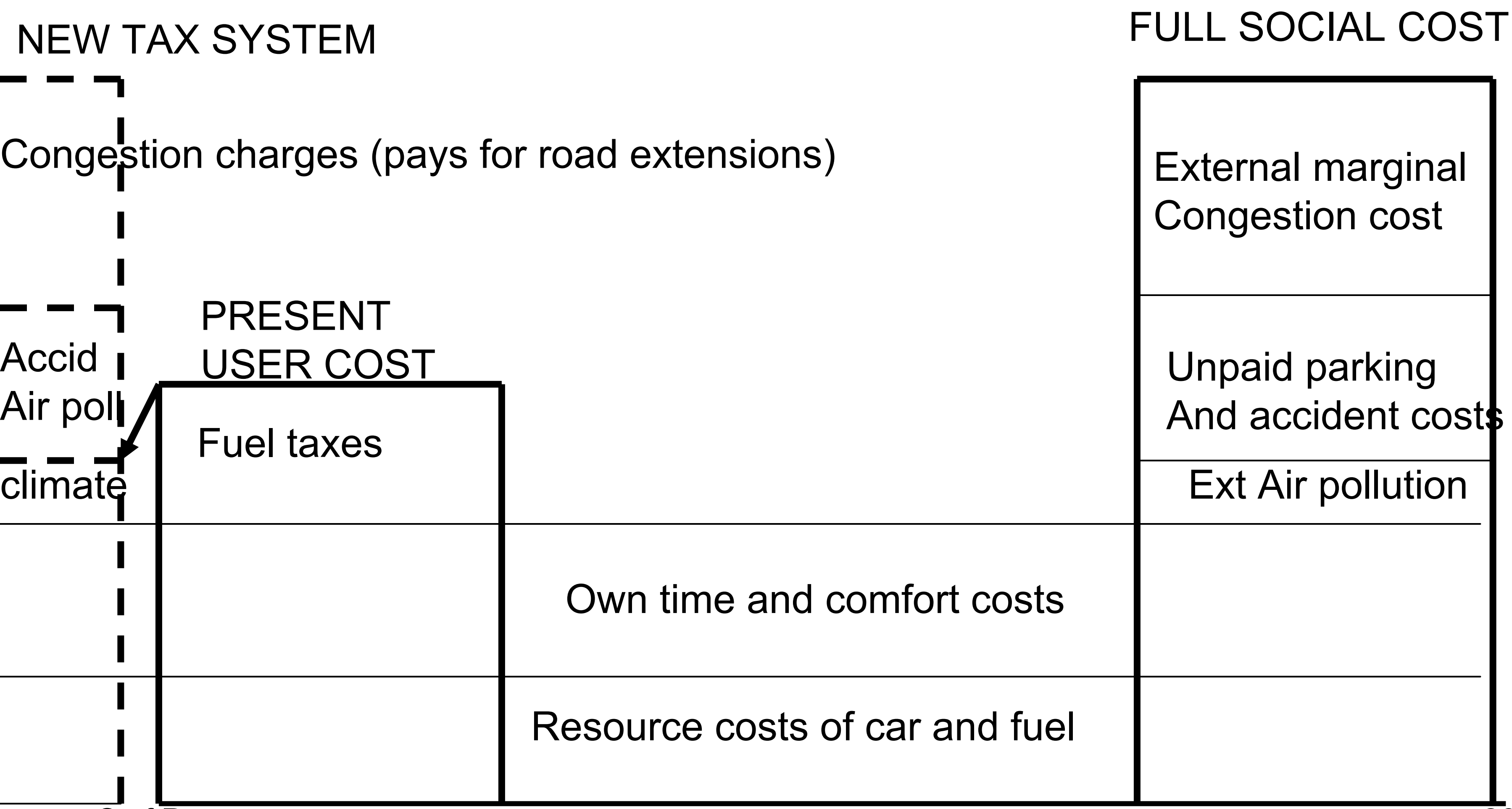
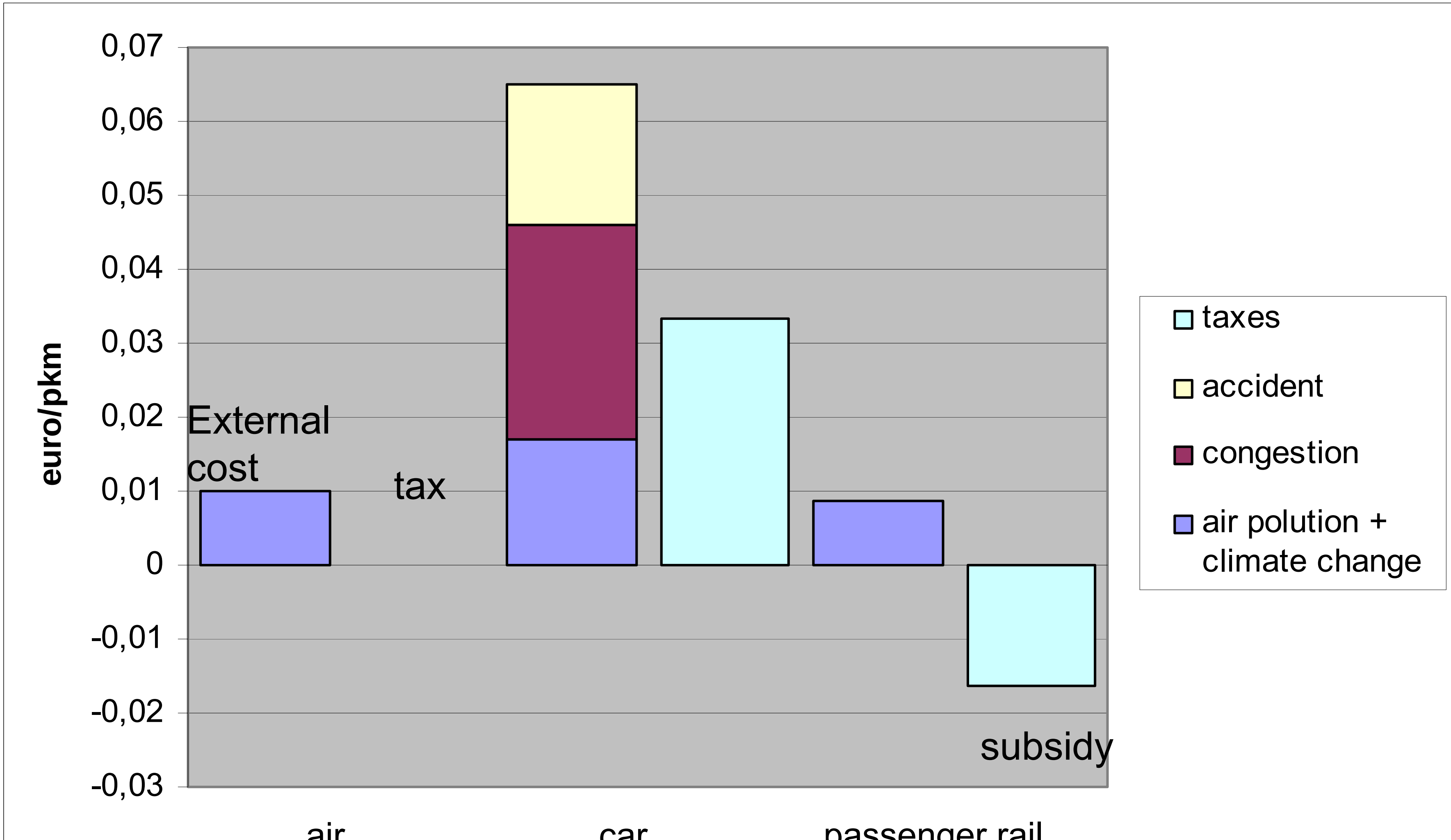


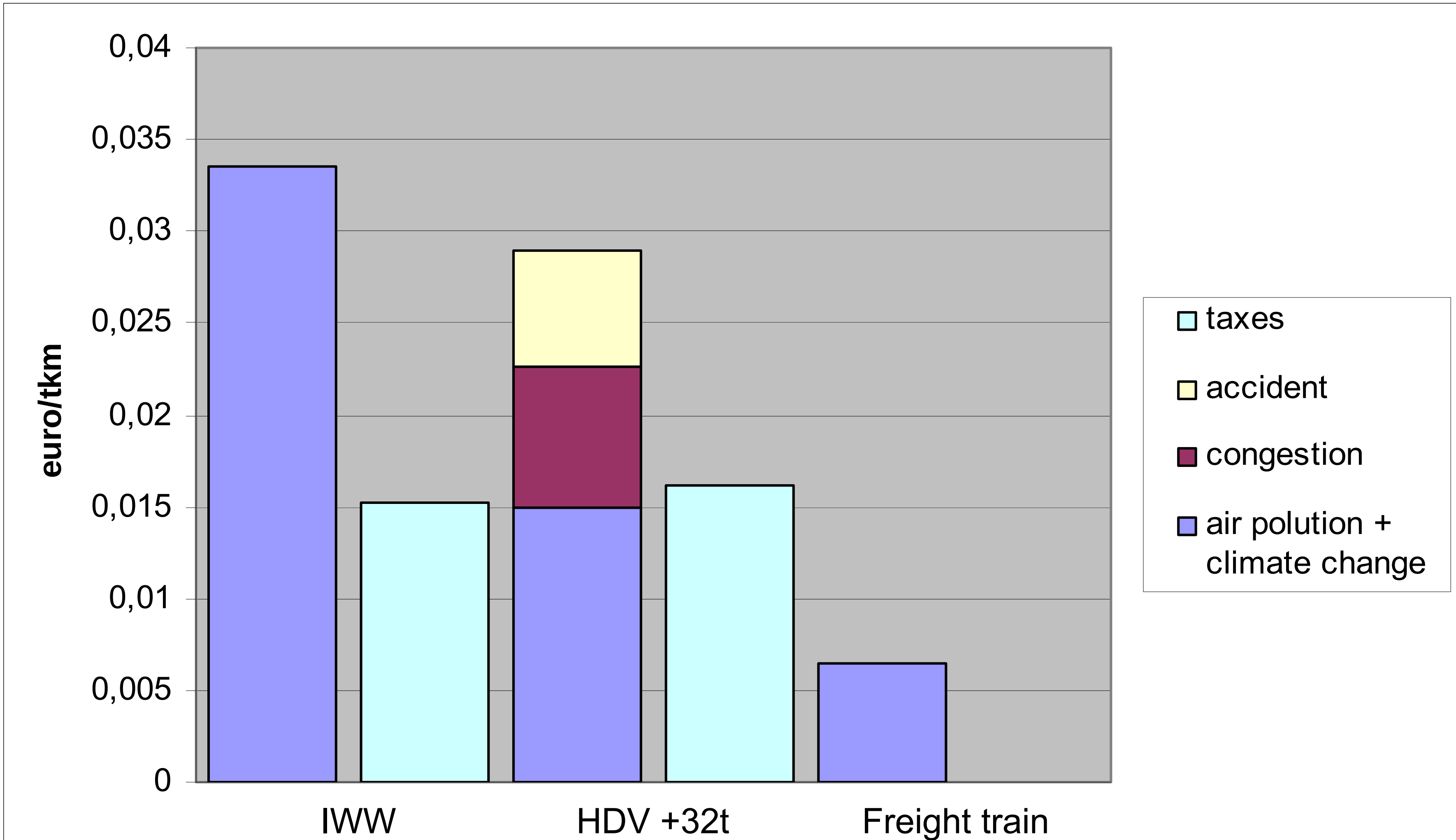
Reference values for external costs

- Computation procedures: see handbook on external costs
- http://ec.europa.eu/transport/sustainable/doc/2008_costs_handbook.pdf

Marginal external costs versus taxes per passenger km BAU 2020



Marginal external costs versus taxes per freight ton km BAU 2020



Can we do better in the transport sector than using high fuel taxes and what would be the outcome?

- Assuming 80 Euro/ ton carbon damage, what would happen if one replaced the high fuel taxes by a 80 Euro/ton CO2 carbon tax + km charges that better reflect the congestion, accident, other air pollution damage in transport?

Effects of replacing fuel taxes by differentiated kmtaxes in EU27+4

2020 – difference with Reference	Revenue	Overall welfare	Total Environmental damage	GHG emission damage
Difference expressed in % of GDP	+3.1%	+1.2%	-0.22%	- 0.054%
	Passenger km on road	Total pass km	Ton km on road	Total ton km
% difference in quantities	-8.6%	-11.5%	-10.1%	-11.0%

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Fuel efficiency regulation cars 1

- European Commission advocates a fuel efficiency standard for cars via "enforced" voluntary agreements
- In 1995: 5 litre/100 km for new cars in 2005, now deferred to 2013
- Motivation for policy:
    - GHG emission reduction
    - Oil import dependency
    - Help myopic consumers
- US is adopting now stricter fuel efficiency standard

Fuel efficiency standards in World

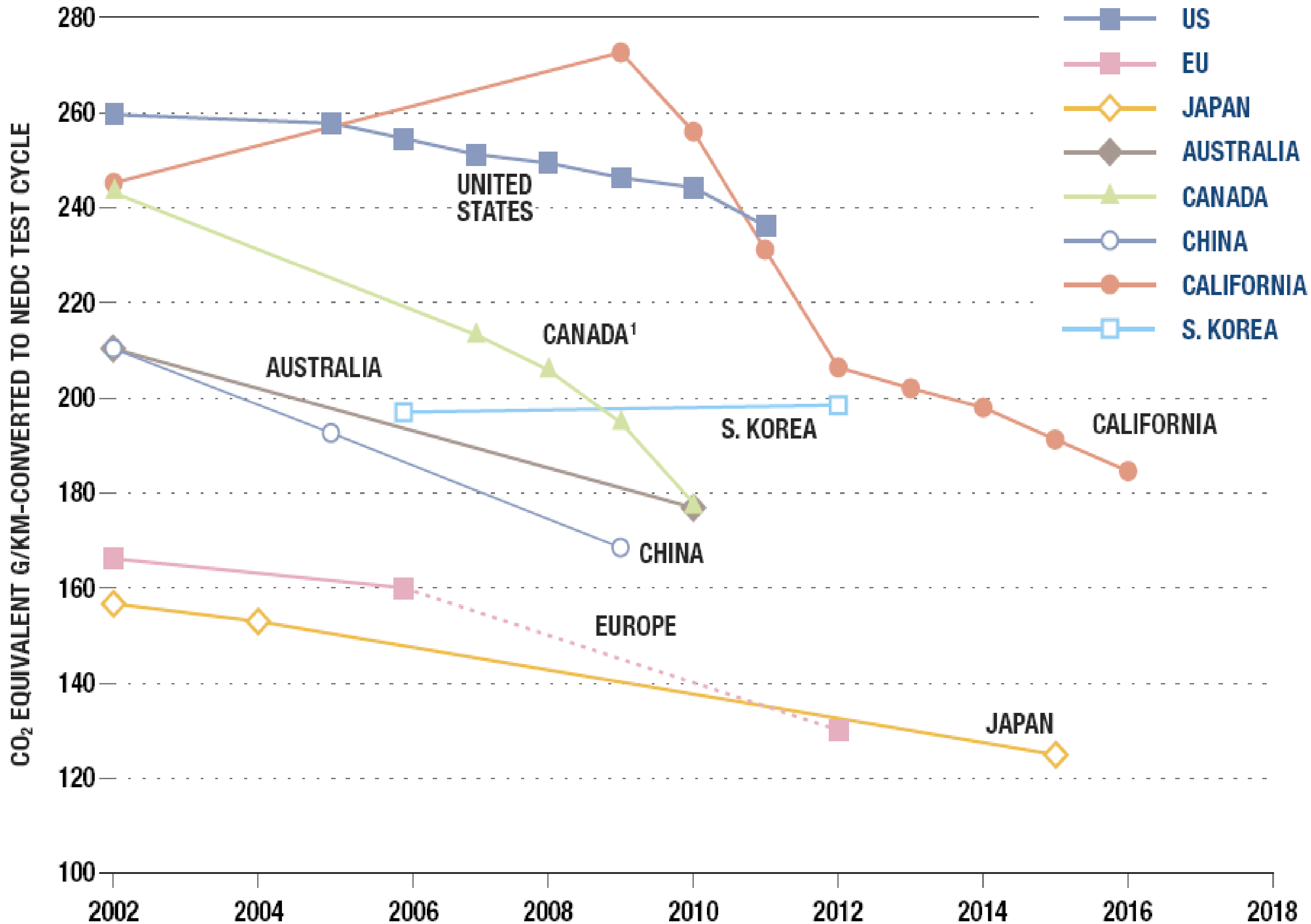


FIGURE ES-1. Actual and Projected GHG Emissions for New Passenger Vehicles by Country, 2002-2018.

Note: Solid lines denote actual performance or projected performance due to adopted regulations; dotted lines denote proposed standards; Values normalized to NEDC test cycle in grams of CO_2-equivalent per km.

[1] For Canada, the program includes in-use vehicles. The resulting uncertainty on new vehicle fuel economy was not quantified.

Mpg regulations World

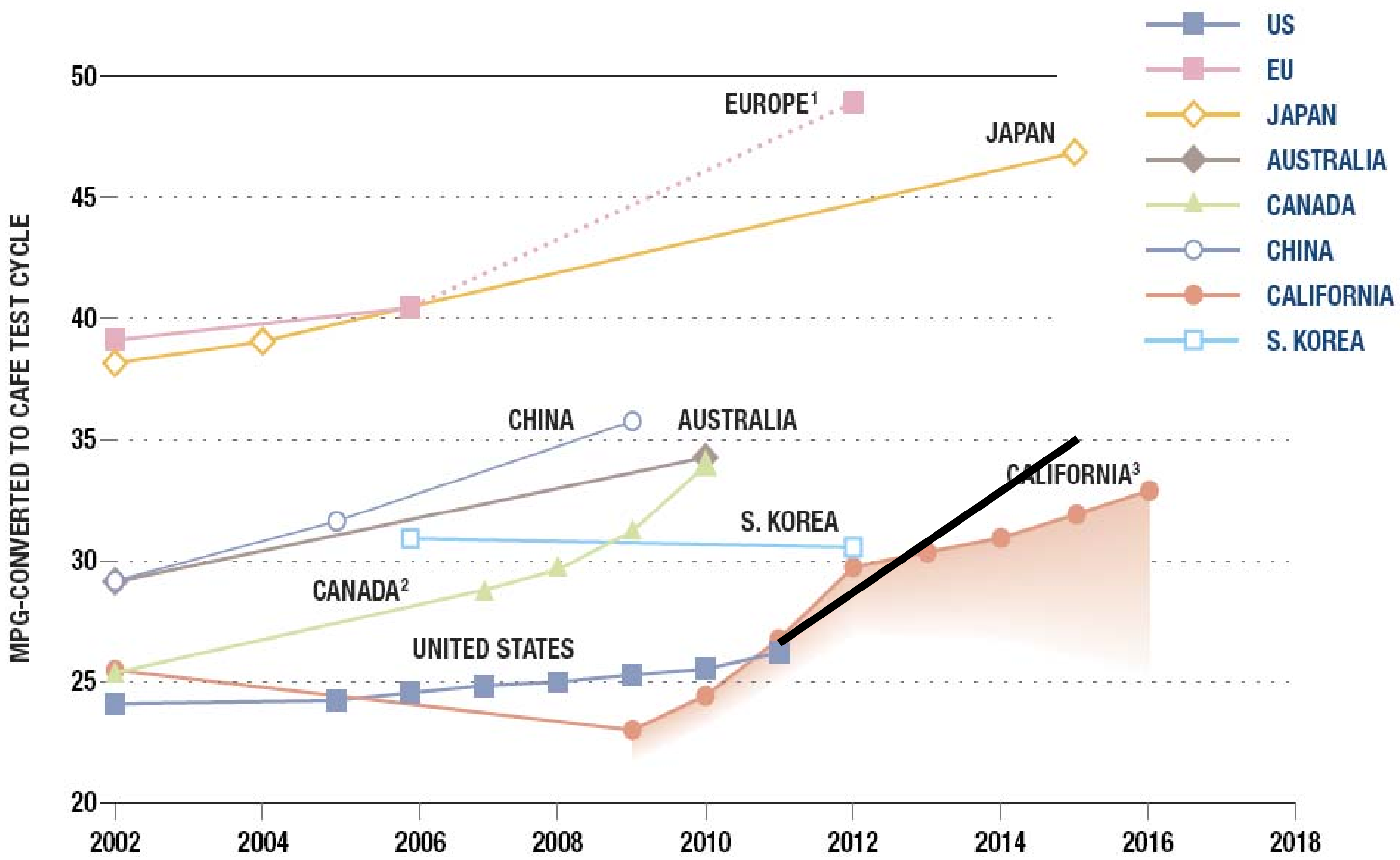


FIGURE ES-2. Actual and Projected Fuel Economy for New Passenger Vehicles by Country, 2002-2018.

[1] The relative stringency of Europe's CO_2-based standards is enhanced under a fuel economy standard because diesel vehicles achieve a boost in fuel economy ratings due to the higher energy content of diesel fuel.

[2] For Canada, the program includes in-use vehicles. The resulting uncertainty of this impact on new vehicle emissions was not quantified.

[3] Shaded area under the California trend line represents the uncertain amount of non-fuel economy related GHG reductions (N_2O, CH_4, HFCs, and upstream emissions related to fuel production) that manufacturers will generate from measures such as low-leak, high efficiency air conditioners, alternative fuel vehicles, and plug-in hybrid electric vehicles.

Fuel efficiency regulation cars 2

- Elementary economics (competitive supply of car services and rational consumers):
  - Car Manufacturers offer cars that, for given quality level, minimize user costs of a car
  - Gross Cost of saving 1 liter of fuel in car services = price of fuel
  - Price of gasoline in EU = 1.4 Euro/litre = 0.5 resource + 0.9 taxes
  - Welfare cost of saving 1 litre of gasoline

    > [0.9 Euro – saved external air pollution costs]

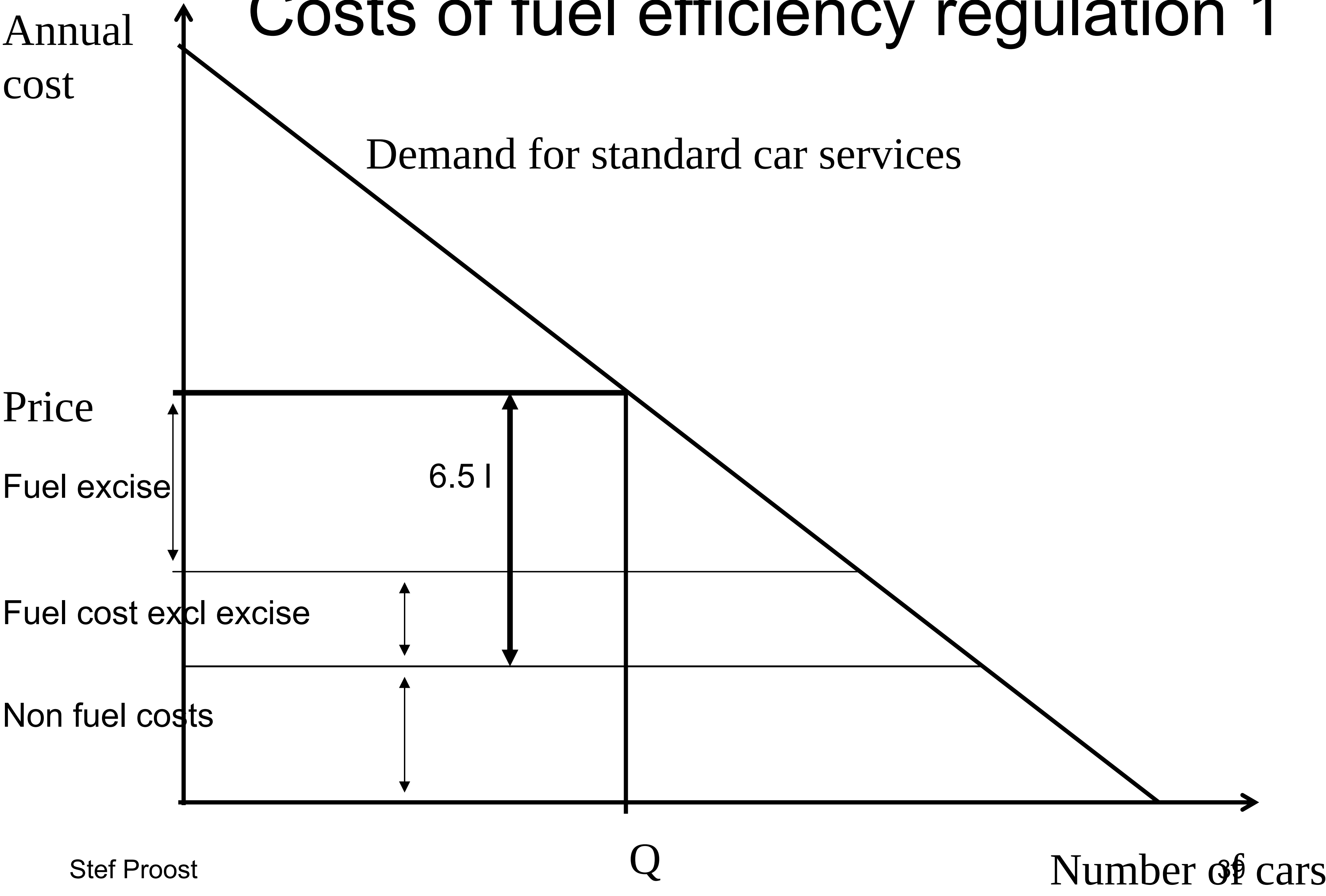
    lower bound on welfare costs

    Because you impose an extra constraint on production process of car services

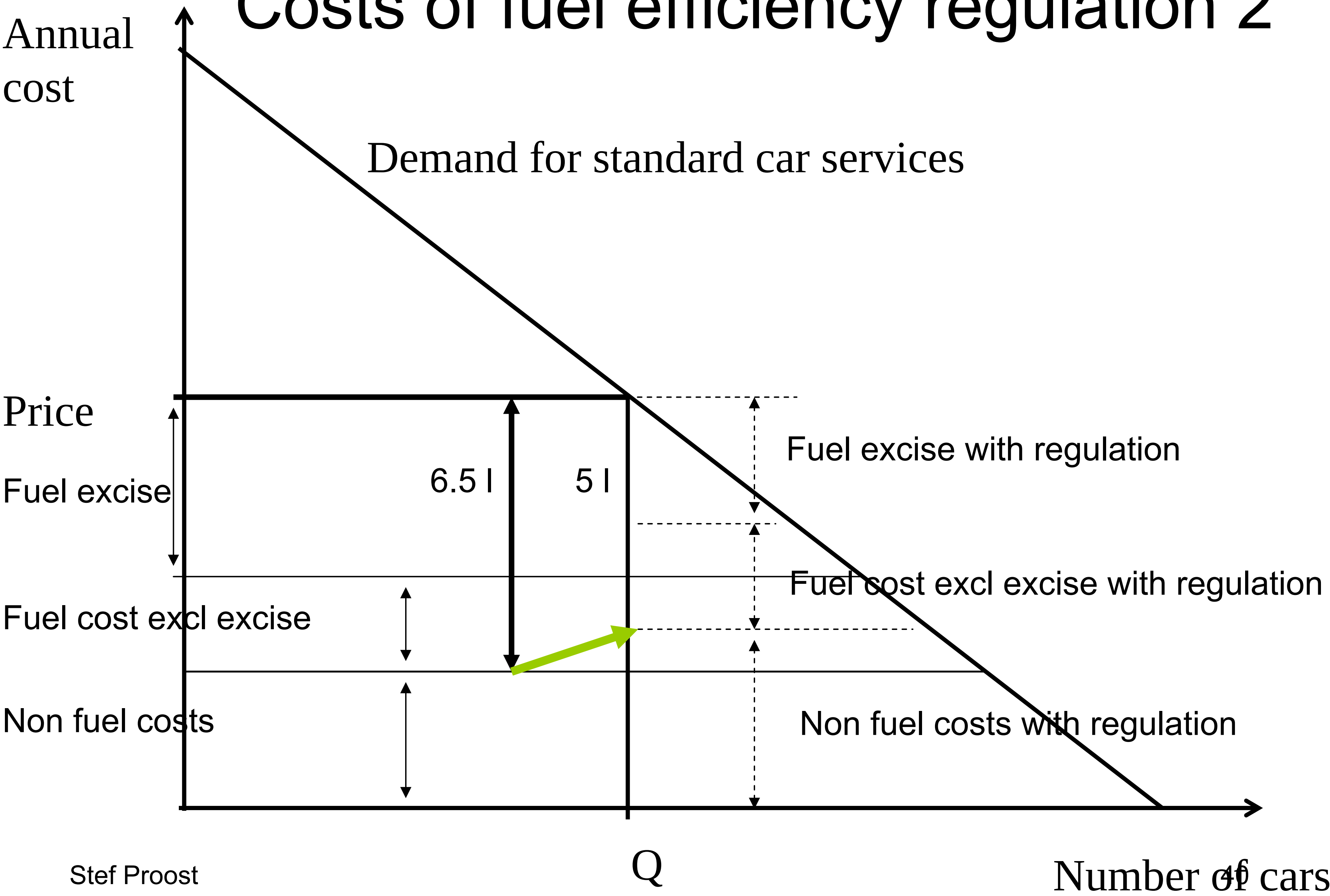
Fuel efficiency regulation cars – example in table

- Example for a medium sized car that consumes 6.5 litre/100km and is forced to consume only 5 litre
  - discount rate 10%, 10 year technical lifetime
  - assumption: average user cost for car do not change (lower bound on costs)
- Cost of saving CO_2 via this measure >500 Euro/ton CO_2
- Cost in other sectors: 20 ? Euro/ton CO_2

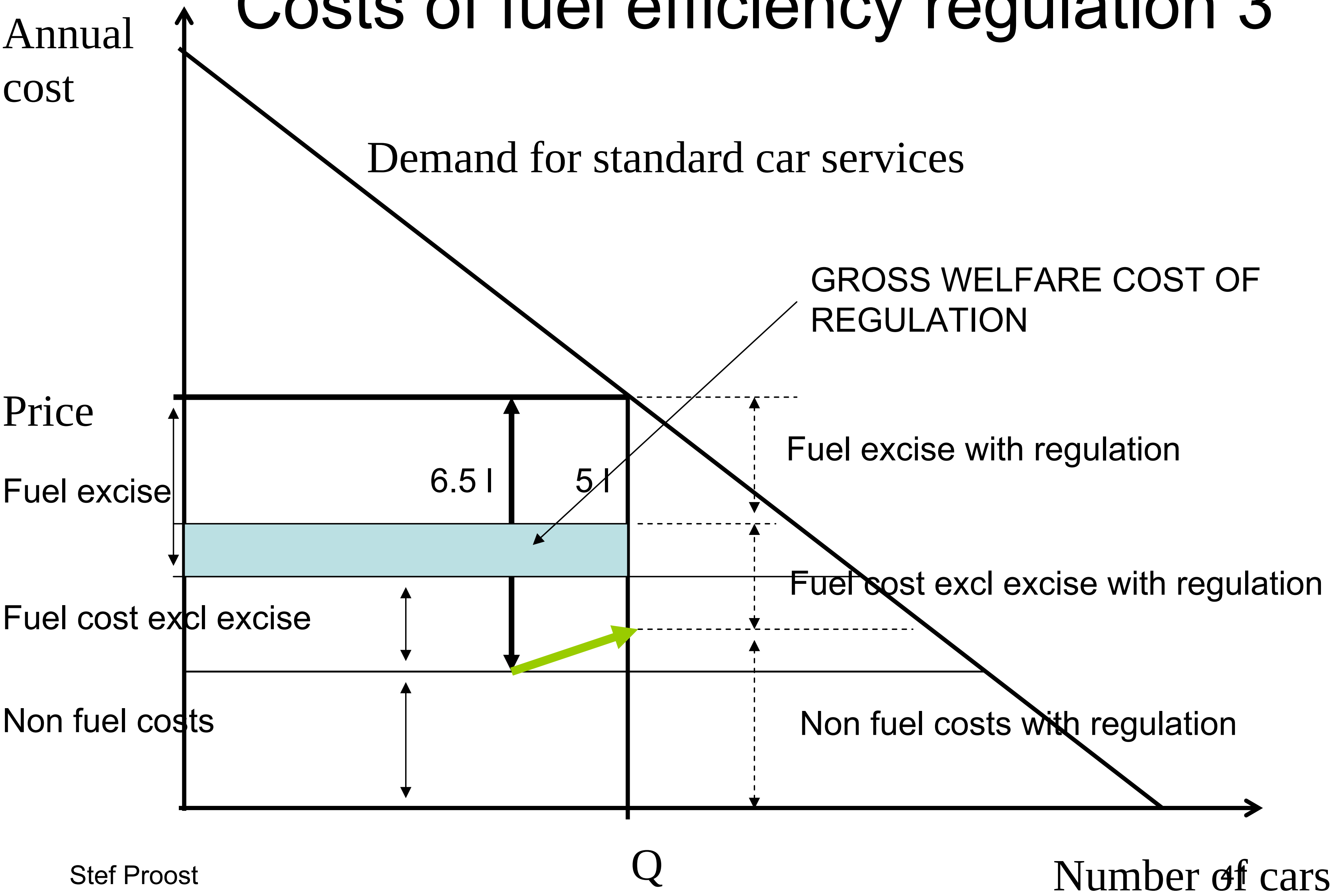
Costs of fuel efficiency regulation 1



Costs of fuel efficiency regulation 2



Costs of fuel efficiency regulation 3



WELFARE COST OF FUEL EFFICIENCY STANDARD

FOR A MEDIUM SIZED CAR ON ANNUAL BASIS USING LOWER BOUND ON COSTS	
INCREASED PRODUCTION COST CAR	+ 332 Euro
SAVED FUEL RESOURCE COSTS (EXCL. EXCISES)	- 138 Euro
SAVED OIL SUPPLY COSTS (10% premium)	- 14 Euro
INCREASED EXTERNAL CONGESTION AND ACCIDENT COSTS DUE TO REBOUND EFFECTS	+ 119 Euro
EXTRA COST OF PUBLIC FUNDS (MCPF=1.5 so 50%)	+ 97 Euro
TOTAL WELFARE COST PER CAR AND PER YEAR	= 374 Euro
TOTAL CO2 QUANTITY SAVED PER YEAR	0.614 Ton
COST PER TON OF CO2 SAVED	**609 Euro**
MARKET PRICE CO2 PERMITS	**5 à 30 Euro**

Details of computation (see Knockaert&Proost)

	Reference	*with Standard*
Fuel consumption per 100 km	6.5 litre ($160g\ CO_2$)	5 litre ($120g\ CO_2$)
Expected vehicle lifetime[1]	10 year	Idem
Real interest rate	10 %	Idem
Annualised car purchase price	€2,441[2]	€2,773[3]
Annual mileage	18,000 km	Idem
Fuel price (excl. excise taxes) per litre[4]	€0.51	Idem
Excise taxes per litre	€0.72	Idem
Saved fuel costs (excl. excise taxes)		€138[5]
Saved fuel excise taxes		€194[6]
User cost per year	€3,880	€3,880

[1] Expected lifetime and interest rate are needed to allow for calculations on an annual base.
[2] Purchase cost of €15,000 × 0.16275 (annuity for 10 years and 10%).
[3] Given our assumption, the annual cost increase per car is computed so as to compensate exactly for the saved fuel costs for the consumer = {1.5 litre less per 100 km × €1.23 per litre × 18,000 km per year}.
[4] This is the maximum price for gasoline on May 10, 2005 (source: Belgian Oil Industry Federation). We split this price into 2 components: the first component excludes excise taxes + VAT (21 %); the second component excises taxes + VAT (21%) on excises.
[5] {1.5 litre less per 100 km × €0.51 per litre × 18,000 km per year}.
[6] {1.5 litre less per 100 km × €0.72 per litre × 18,000 km per year}.

Fuel efficiency regulation cars 3

- Myopic consumer? empirical evidence is different
- Behaviour of car producers in monopolistic competition?
- IS there a regulation ? 1995 – 2005 - 2010 -…
- WHY does this regulation exist?
  - Fairness (transport sector does its share…..)
  - Consumers reason in after tax prices of fuel
  - Consumers don't see the costs as car models change quickly over time and no car producer has an interest to tell that his car has become more costly because of the regulation
  - **Decision making at EU level has Ministers of Environment deciding on standards because fuel excise tax rates are not changed, only the effective tax base is reduced**

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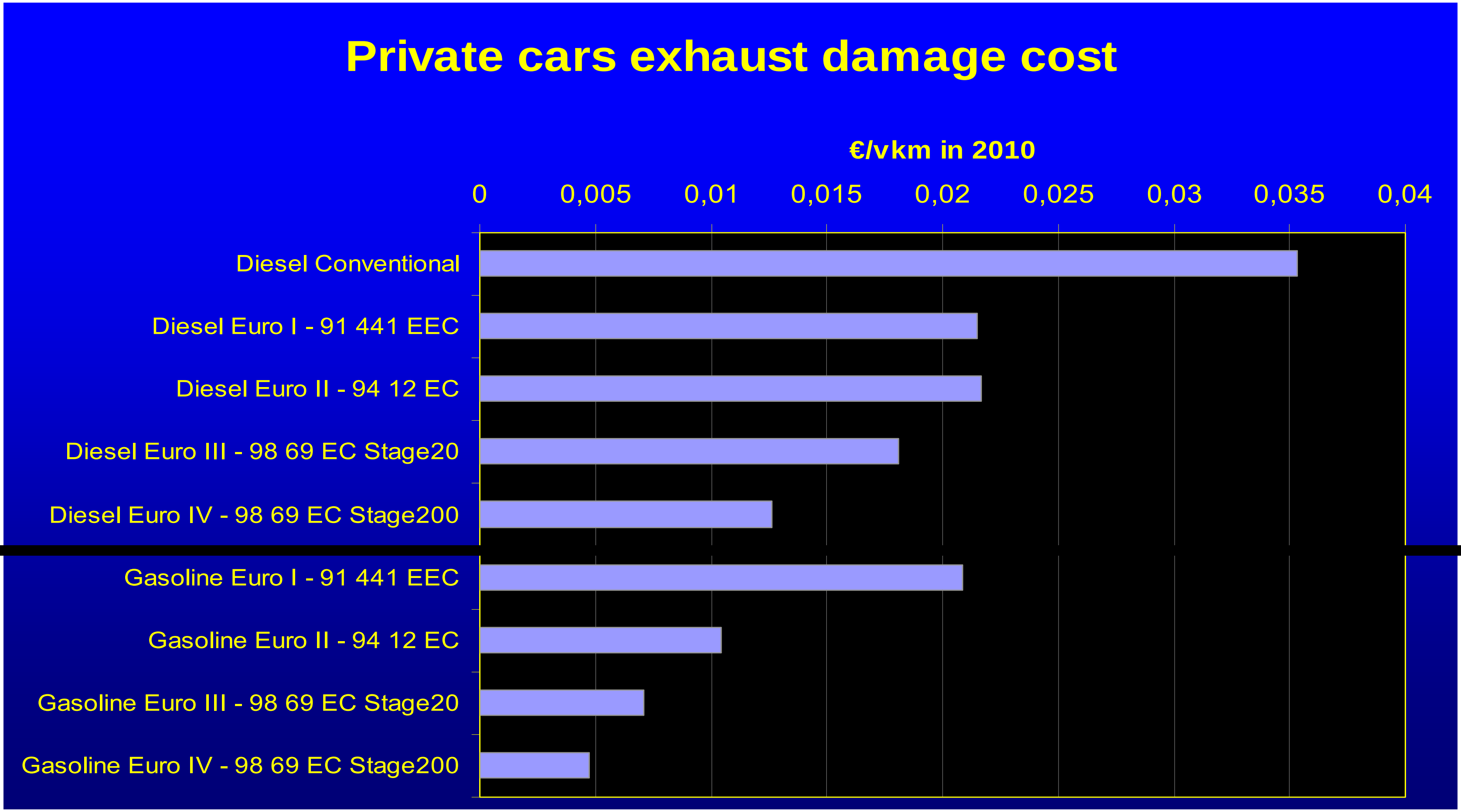
Environmental damage of different vintages of diesel and gasoline cars



Diesel-Gasoline controversy 1

- Diesel compared to gasoline is
  - More fuel efficient (so less CO2 emissions)
  - But counting all pollutants (particles) more damaging for environment (1.4 Euro/ 100 km vs 0.5 Euro/100 km)
  - Diesel cars pay less taxes per Vehicle km in most EU countries
- RESULT: High market share for new diesel cars in some countries (up to 70%)
- Puzzle: why is a technology encouraged (pays less taxes) that has higher Social Marginal Cost ?

Diesel-Gasoline controversy 2

- Puzzle: why is a technology encouraged (pays less taxes) that has higher SMC?
  - Lag in government regulation?
    - Technology revolution diesel cars since early 90 ties
    - Health damage of small particles is “recent” knowledge
  - Finance ministers’ business
  - Overemphasis in transport sector on fuel consumption (and CO2 emissions)

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Long term fuel choice issues 1

- What type of fuel will be used in our cars?
- Comparison of technologies on the same basis:
  - Environmental costs
  - User costs (= resource costs excluding taxes)

Alt. Techn.: TREMOVE

Long term fuel choice issues 2

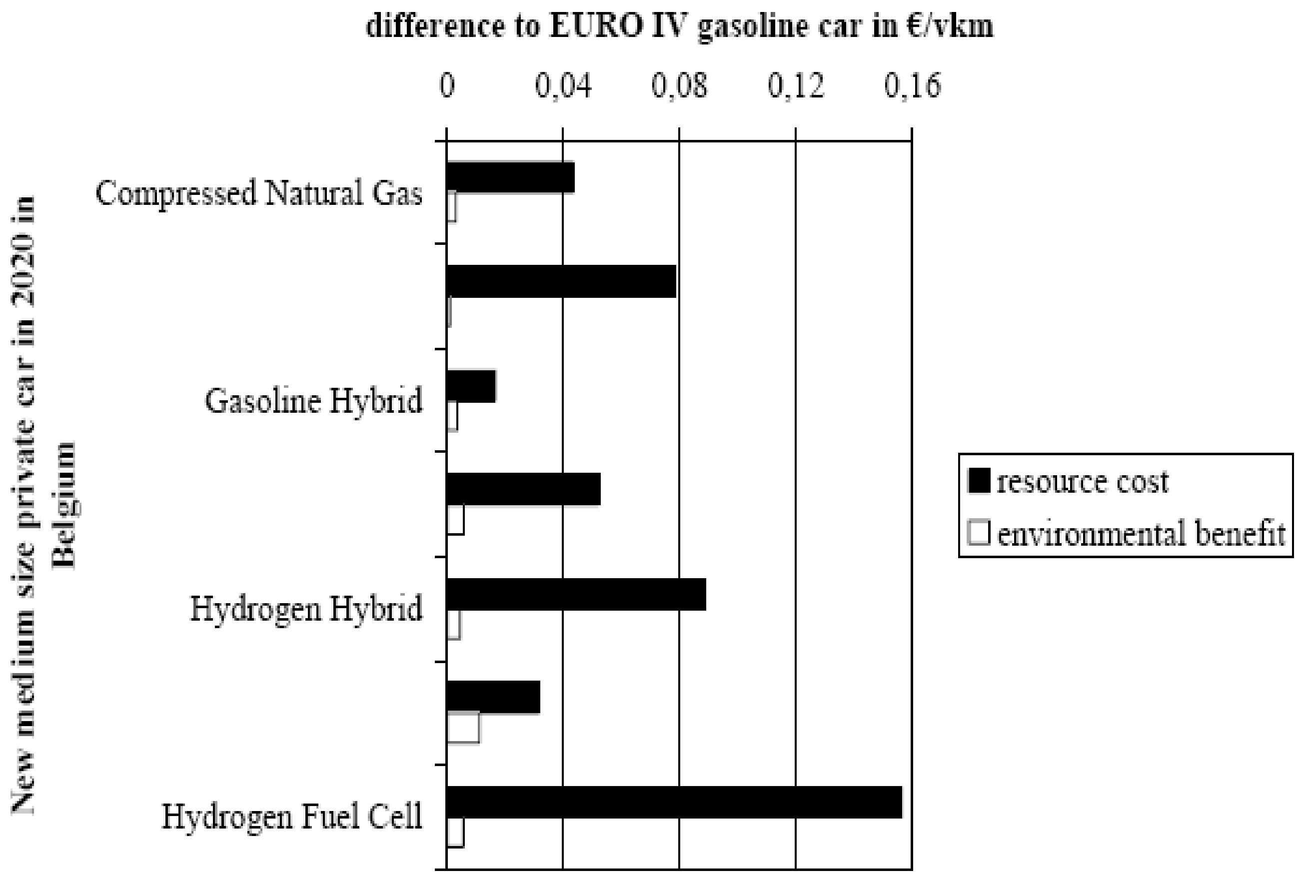

Figure 2: cost-benefit comparison of new technologies

Investment Cost reduction needed to make a new technology interesting (source MARKAL)

	2020	2030	2040
Biodiesel	21%	13%	0%
Hydrogen.Combustion	56%	59%	45%
Diesel.EURO4	1%	1%	7%
Electric.Battery	41%	146%	163%
Hydrogen.FuelCell	58%	29%	20%
Hydrogen.Hybrid.FuelCell	59%	34%	25%
Gasoline.CNG	3%	0%	0%
Gasoline.EURO4	0%	0%	7%
Diesel .EURO4.parallelhybrid	18%	17%	20%
Gasoline.CNG.parallelhybrid	13%	8%	4%
Gasoline.EURO4.parallelhybrid	6%	3%	1%
Hydrogen.Hybrid.Combustion	57%	63%	49%

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Is PAYD insurance a good way to deal with accident and air pollution externalities ?

based on I. Parry (AER proceedings 2005, but we use RFF disc paper)

Issues

- Externalities of two types
  - Mileage related: accidents, congestion
  - Fuel related:
    - greenhouse gasses,
    - oil dependency (use monopsony power on oil market + limit effect of interruptions)
- Compare two simple policy solutions:
  - Higher fuel taxes (in US, fuel taxes are low)
  - PAYD insurance: switch from current lumpsum payment per year per vehicle to mileage related premiums that are scaled by driver's record
- Both solutions have to be comparable:
  - the same overall reduction of fuel demand needs to be reached
  - one opts for the solution with the lowest net social cost

Model with representative consumers – no labour supply and only car transport

$$U = u(C, M) - E_F(\overline{F}) - E_M(\overline{M}), \quad M = vm$$

Where C is general consumption good

M is mileage = number of vehicles ***v*** times mileage per car **m**

Each consumer takes as given the total fuel use in the economy Fbar
E_F represents the disutility of fuel related externalities that is related to the total consumption of fuel, ex: climate change..)

Each consumer takes as given the total mileage in the economy Mbar
E_M represents the disutility of mileage related externalities (congestion, Accidents) – THIS IS SIMPLIFIED FORMULATION WHERE LEVEL OF EXTERNALITY DOES NOT HAVE IMPACT ON TOTAL VEHICLE MILES (utility is additively separable in m and Mbar)

$$U = u(C,M) - E_F(\overline{F}) - E_M(\overline{M}), \quad M = vm$$

The agent's budget constraint is as follows:

$$(2a) \quad C + v(p_v + p_m m) = I + G + \pi$$

$$(2b) \quad p_m = p_F / f + p_i + t_M + \theta(m), \qquad p_F = q_F + t_F$$

$$(2c) \quad p_v = p_a + p_P(f)$$

Where I labour income,π profit income and G transfer of government are Exogenous

Pv is fixed cost of owning a vehicle, Pm is variable cost per mile

Pm = price of fuel Pf divided by fuel efficiency f in miles per gallon + insurance price per Mile Pi + mileage tax Tm + maintenance cost θ(m)

{θ(m) increases with m and guarantees that more than one vehicle is bought}

Pf price of fuel = resource cost Qf + tax on fuel Tf

Pv fixed cost of owning a car = Pa annual insurance premium + Pp(f) resource cost per year of a car, this cost is an increasing function of the fuel efficiency

Government budget constraint: all fuel taxes are redistributed

$$G = t_F F \,, F = M / f$$

Competitive firms supply cars, fuel and insurance at marginal cost and given constant returns to scale make no profits:

(4) $$\pi = v(p_a + (p_i - x)m) \equiv 0$$

where x is the expected insurance claim per mile driven (reflecting property damages and a portion of medical services). Profits accrue to households who own firms and are zero in equilibrium.

We are interested in comparing the effects of a small, budget neutral (via increase of lump sum transfer G) increase

1) in the Fuel tax
2) in a tax per vehicle mile and in
3) a Pay as You Drive insurance fee

That produce all the same decrease in overall fuel consumption

In the derivation in appendix of Parry,

- First line= definition of indirect utility function (taking externalities as given) , ! Misprint in the budget constraint that should read

$$I+G+\pi-C-v\left[p_a+p_p(f)+m\left\{t_m+p_i+\theta(m)+(q_F+t_F)/f\right\}\right]$$

- Second line (A2)= derivation of indirect utility function (using identity of Roy)

- Third line (A3)= total differential of indirect utility function, for a budget neutral increase in a Fuel tax recycled via higher lump sum payment

(A1) $$V(t_F, p_i, p_a, t_M, G, \pi, E_F, E_M) = \underbrace{MAX}_{C,m,v} u(C, mv) - E_F - E_M$$

$$+ \lambda\{I + G + \pi - C - v[p_a + p_P(f) + t_M + m(p_i + \theta)m] - (q_F + t_F)F\}$$

where $V(.)$ is indirect utility.

Partially differentiating (A1) gives:

(A2) $$V_{t_F} = -\lambda F\,,\; V_{p_i} = -\lambda M\,,\; V_{p_a} = -\lambda v\,,\; V_{t_M} = -\lambda M\,,\; V_G = V_\pi = \lambda\,,\; V_{E_F} = V_{E_M} = -1$$

Totally differentiating the indirect utility function in (A1) with respect to t_F, keeping p_i, p_a and t_M constant, gives:

(A3) $$\frac{dV}{dt_F} = V_{t_F} + V_\pi \frac{d\pi}{dt_F} + V_G \frac{dG}{dt_F} + V_{E_F} E'_F \frac{dF}{dp_F} + V_{E_M} E'_M \frac{dM}{dp_F}$$

Using (3), (4), (6), with $p_i = 0$:

(A4) $$\frac{dG}{dt_F} = F + t_F \frac{dF}{dt_F}, \frac{d\pi}{dt_F} = -xv\frac{dm}{dt_F}$$

Substituting (A2) and (A4) in (A3), and dividing by λ, and using $p_a = xm$, gives (5), where $dW / dt_F = (dV / dt_F) / \lambda$.

(i) Gasoline tax. The welfare change (in dollars), denoted W, from a marginal increase in t_F can be expressed (see Appendix) thus:

$$(5) \qquad \frac{dW}{dt_F} = \left\{ t_F - \frac{E'_F}{\lambda} \right\} \frac{dF}{dp_F} + \left\{ p_a - m\frac{\widetilde{E}'_M}{\lambda} \right\} \frac{dv}{dp_F} - \frac{\widetilde{E}'_M}{\lambda} v \frac{dm}{dp_F}$$

where λ is the marginal utility of income and $\widetilde{E}'_M = E'_M + x$ denotes marginal external mileage costs, inclusive of costs borne by insurance companies. All of the three price coefficients are assumed negative.

First effect= welfare effect on gasoline market (NEGATIVE if tax exceeds MEC)

Second effect = welfare effect on car market (NEGATIVE if annual insurance payment is Larger than the external effect per vehicle)

Third effect= welfare effect due to reduction in mileage per vehicle (POSITIVE as there Is an external cost (congestion+energy sec +accidents) associated to every mile)

We assume demand for fuel, vehicles, and miles per vehicle respond to fuel prices as follows:

$$(6) \qquad \frac{F}{F_0} = \left(\frac{p_F}{p_F^0}\right)^{\eta_{FF}}, \quad \frac{m}{m_0} = \left(\frac{p_F}{p_F^0}\right)^{\beta_M \beta_m \eta_{FF}}, \quad \frac{v}{v_0} = \left(\frac{p_F}{p_F^0}\right)^{\beta_M (1-\beta_m) \eta_{FF}}$$

where $\eta_{FF} < 0$ is the gasoline demand elasticity. This reflects changes in fuel economy and in VMT; the latter reflects reduced miles per vehicle (for a given vehicle stock) and reduced demand for vehicles (for a given miles per vehicle). β_M is the (constant) fraction of reduced gasoline that comes from reduced VMT, and β_m is the (constant) fraction of reduced VMT that comes from reduced miles per vehicle.

(iii) VMT tax. For this policy, we assume demand functions are as follows:

$$(8) \qquad \frac{F}{F_0} = \left(\frac{p_F^0 + t_M f^0}{p_F^0} \right)^{\beta_M \eta_{FF}}, \quad \frac{m}{m_0} = \left(\frac{p_F^0 + t_M f^0}{p_F^0} \right)^{\beta_M \beta_m \eta_{FF}}, \quad \frac{v}{v_0} = \left(\frac{p_F^0 + t_M f}{p_F^0} \right)^{\beta_M (1-\beta_m) \eta_{FF}}$$

That is, we convert the VMT tax into its equivalent fuel tax at initial fuel economy and use the same elasticities as before, except that because fuel economy is unchanged, we assume fuel demand responds only to the mileage component of the fuel demand elasticity, $\beta_M \eta_{FF}$.

(ii) PAYD. An increase in the per mile insurance cost p_i is equivalent to an increase in the VMT tax t_M, except that revenues are rebated to consumers in a lower annual fee, p_a. We assume no change in vehicle demand[8]; hence, analogous to (9) and (10), demand functions and the marginal welfare effects are as follows:

$$(10) \qquad \frac{F}{F_0} = \left(\frac{p_F^0 + p_i f^0}{p_F^0} \right)^{\beta_M \beta_m \eta_{FF}}, \quad \frac{m}{m_0} = \left(\frac{p_F^0 + p_i f^0}{p_F^0} \right)^{\beta_M \beta_m \eta_{FF}}$$

The welfare effect of reducing total fuel consumption
By a revenue neutral increase in the FUEL TAX and in the VMT tax are now:
(each time decomposed into fuel market effect, vehicle market effect and fuel efficiency effect

$$(7) \qquad -\frac{dW/dt_F}{dF/dt_F} = \frac{E'_F}{\lambda} - t_F + \left\{\frac{\tilde{E}'_M}{\lambda} - \frac{p_a}{m}\right\} f\beta_M(1-\beta_m) + \frac{\tilde{E}'_M}{\lambda} f\beta_M\beta_m$$

Assuming $\tilde{E}'_M/\lambda > p_a/m$, for a given reduction in fuel demand, the larger the fraction of it that comes from reduced VMT, the larger the "ancillary" welfare gain from reduced mileage externalities.

$$(9) \qquad -\frac{dW/dt_M}{dF/dt_M} = \frac{E'_F}{\lambda} - (t_F^0 + t_M f^0) + \left\{\frac{\tilde{E}'_M}{\lambda} - \frac{p_a}{m}\right\} f^0(1-\beta_m) + \frac{\tilde{E}'_M}{\lambda} f^0\beta_m$$

A VMT tax has as main difference with the fuel tax that the effects on the vehicle miles
Related externalities is not reduced by the factor β_M and that a relatively higher tax
Increase is needed to reduce the total gasoline consumption

The welfare effect of reducing total fuel consumption by an increase in the per mile insurance premium

Compensated by a decrease in the annual insurance premium is now:
(decomposed into fuel market effect, vehicle market effect that is equal to 0 and Miles per vehicle effect)

$$(11) \qquad -\frac{dW/dp_i}{dF/dp_i} \approx \frac{E'_F}{\lambda} - (t_F^0 + p_i f^0) + \frac{\widetilde{E}'_M}{\lambda} f^0 \beta_m$$

Compared to the fuel tax, one needs a higher distortion on the fuel market to achieve the same fuel reduction but the welfare gain from reduced Vehicle miles is higher because all of it comes from reduced miles

Table 1. Parameter Values

Parameter	Value	Source
Components of fuel-related externalities		
carbon emissions, cents/gal.	12.0	NRC (2002)
oil dependency, cents/gal.	12.0	NRC (2002)
sum, cents/gal.	24.0	
Components of mileage-related externalities		
congestion costs, cents/mi.	6.5	Parry et al. (2004)
accident costs, cents/mi.	4.0	Miller et al. (1998)
local pollution, cents/mi.	1.5	Parry et al. (2004)
sum, cents/mi.	12.0	
Total fuel demand elasticity	-0.55	Parry/Small (2004)
portion due to reduced VMT	0.4	Parry/Small (2004)
portion of VMT component due to mi./veh.	0.67	Johansson and Schipper (1997)
Initial gasoline tax, cents/gal.	40	Parry/Small (2004)
Initial retail gasoline price	150	Parry/Small (2004)
Initial (on road) fuel economy, mi./gal.	20	Parry/Small (2004)
Initial annual gasoline consumption, billion gals.	130	EIA (2002)
Current insurance costs, cents/mi.	6.5	Litman (2001)

Figure 1. Welfare Effect under Fuel Tax

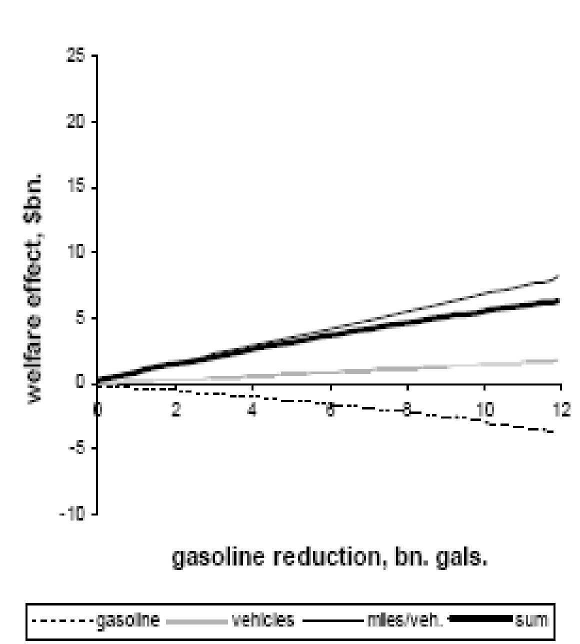


Figure 2. Welfare Effect under VMT tax

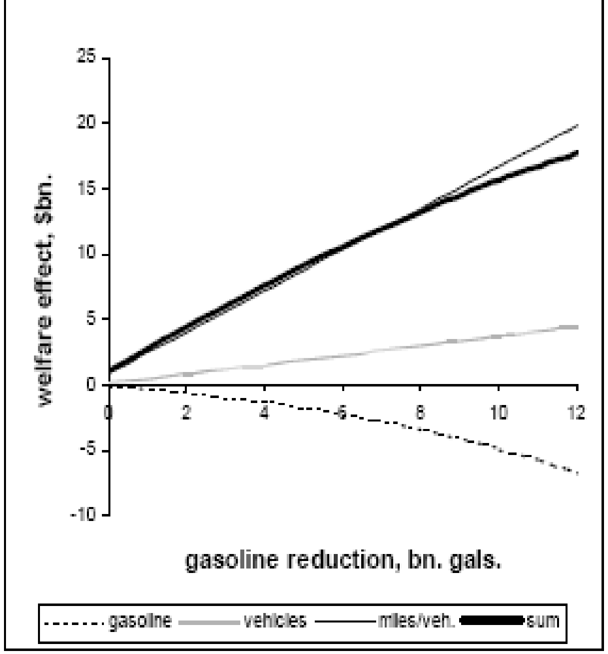
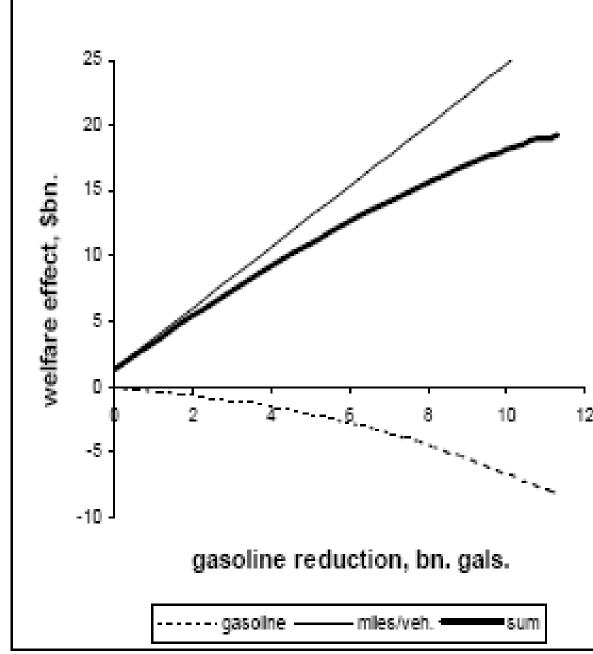


Figure 3. Welfare Effect under PAYD



Accident externalities: Conclusions and caveats

- Welfare gains from reducing gasoline are 3 times higher using PAYD than using a gasoline tax
- So it is in general important to consider all external effects from gasoline use
- For EU: gasoline tax is already much higher so negative gasoline market effect will be much higher
- Analysis understates PAYD benefits because we ignore beneficial effect on heterogeneous drivers
- Analysis overstates effect of PAYD because expected annual insurance premiums that are experience rated are a positive function of miles driven

References and websites

- TREMOVE model analysis www.tremove.org
- EU statistics http://ec.europa.eu/transport/publications/statistics/statistics_en.htm
- EU handbook external costs (policy document) http://ec.europa.eu/transport/sustainable/doc/2008_costs_handbook.pdf
- US: see Parry, Walls and Harrington, Automobile externalities and policies, JEL, June 2007, p 373-399

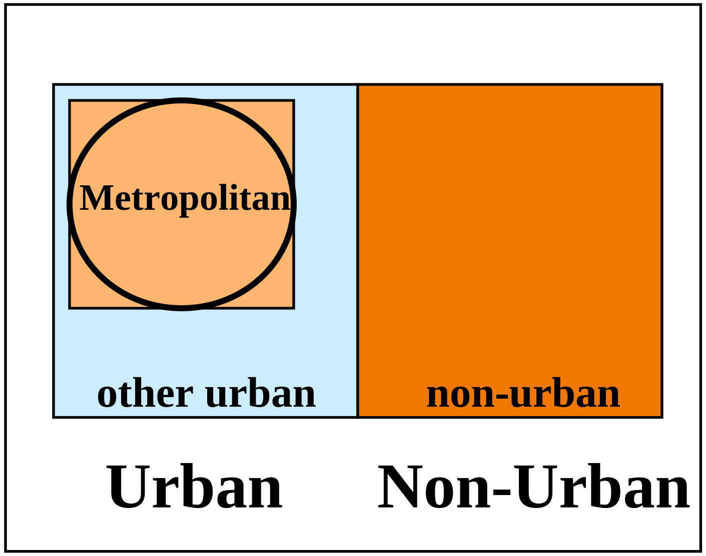
Note: TREMOVE - structure

- See www.tremove.eu

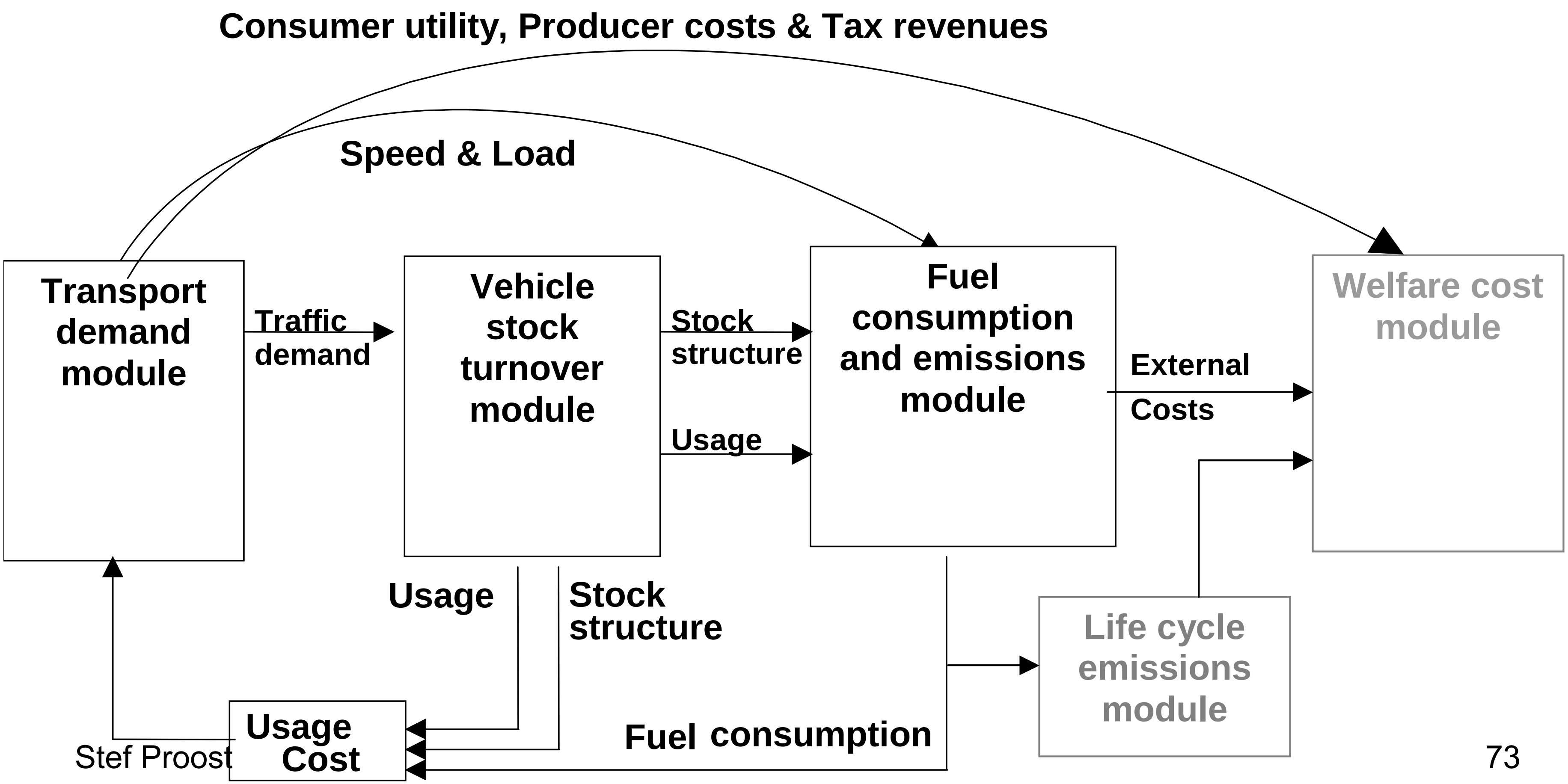
Scope of the model and baseline

2. Geographical coverage (model regions)

Each country consists of 3 model regions



Model specification : Modules



Scope of the model and baseline

3. Modal coverage (passenger transport)

- Car
- Motorcycle
- Bus
- Tram
- Coach
- Metro
- Train (inter-regional)
- Train (international)new
- Air (new)
- Non-motorised
- Ferries

Scope of the model and baseline

3. Modal coverage (freight transport)

- Heavy duty truck
- Light duty truck
- Inland waterway
- Rail
- Truck - Rail (new)
- Truck – Waterway (new)
- Maritime(new)

Scope of the model and baseline

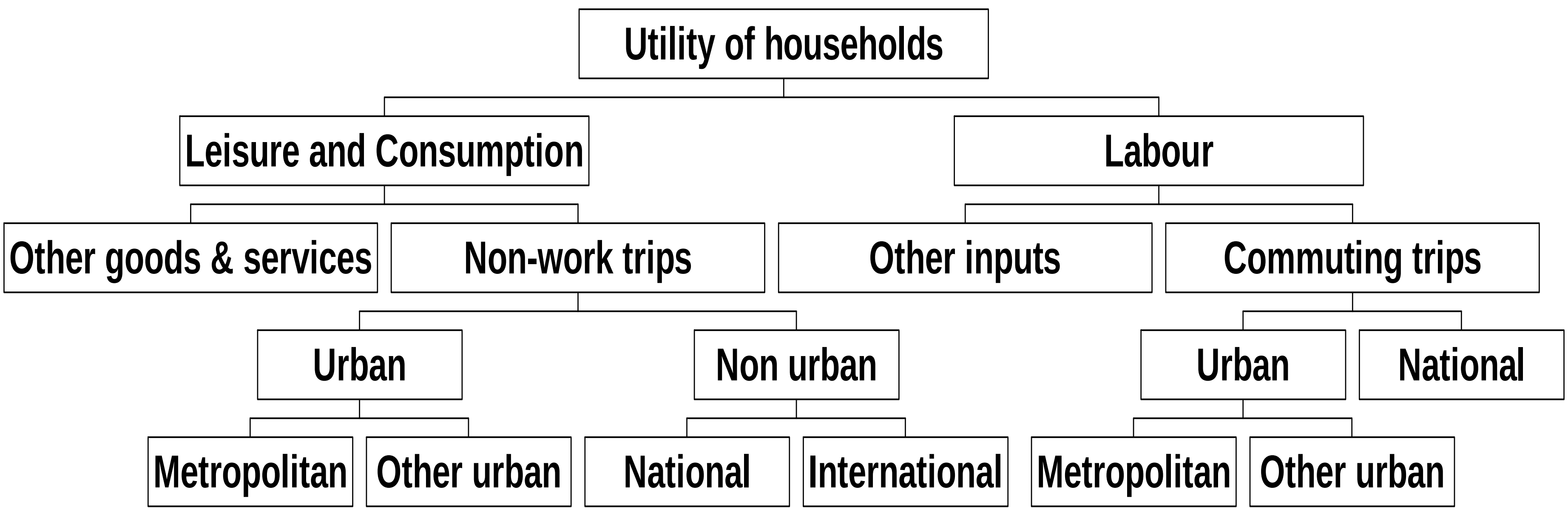
5. Pollutants (as available from ARTEMIS / PARTICULATES)

- CO
- NO_x
- SO_2
- VOC
  - CH_4
  - C_6H_6
  - PAHs
- H_2S (new)

- Particulate Matter (& size distribution)
- $NH_{3\ new}$
- Pb (new)
- Other heavy metals (new)
- CO_2
- N_2O (new)
- Additional GHG (HFC, SF_6, PFC, HCFC)

Model specification : Demand

Non-work and commuting-to-work trips: Nested utility function (CES)



Model specification : Demand

Lower levels of utility function : choice of time of day and mode