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# *The (In-)Efficiency of Weight-Based Vehicle Emission Standards*

**Carl-Friedrich Elmer**

Berlin University of Technology
**W**orkgroup for **I**nfrastructure **P**olicy

*Contact: cae@wip.tu-berlin.de*

# Agenda

**Introduction**

**Economic Rationale of Vehicle Emission Standards**

**Uniform vs. Weight-based Standards**

**Implications for Europe**

**Tradable Vehicle Emissions Standards**

**Conclusion**

# Introduction

- **Transport is a major contributor of Greenhouse Gases (GHG): It accounts for roughly a quarter of global $CO_2$-emissions**

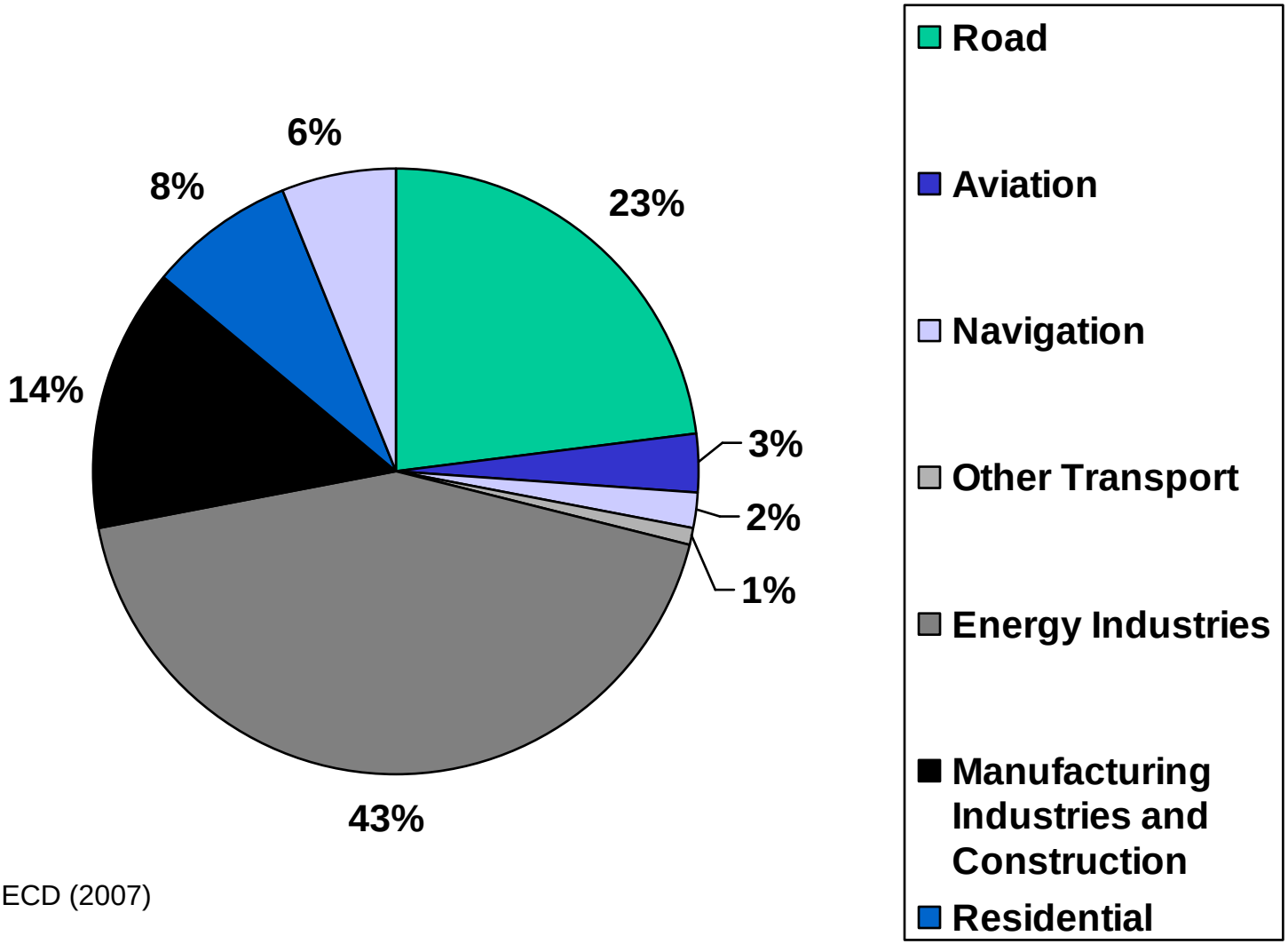
- **Transport's share is lower in developing countries than in developed countries (OECD), but it is rapidly increasing**

- **In the EU, transport emission have significantly increased, while most sectors in the EU could reduce their emissions over the past years**

- **The major part of transport emissions originates from road transport**

- **Passenger transport still dominates road transport emissions, although in developed countries growth in road transport results mainly from increasing freight transport**

# Transport's Share of $CO_2$-Emissions in the OECD




Source: OECD (2007)

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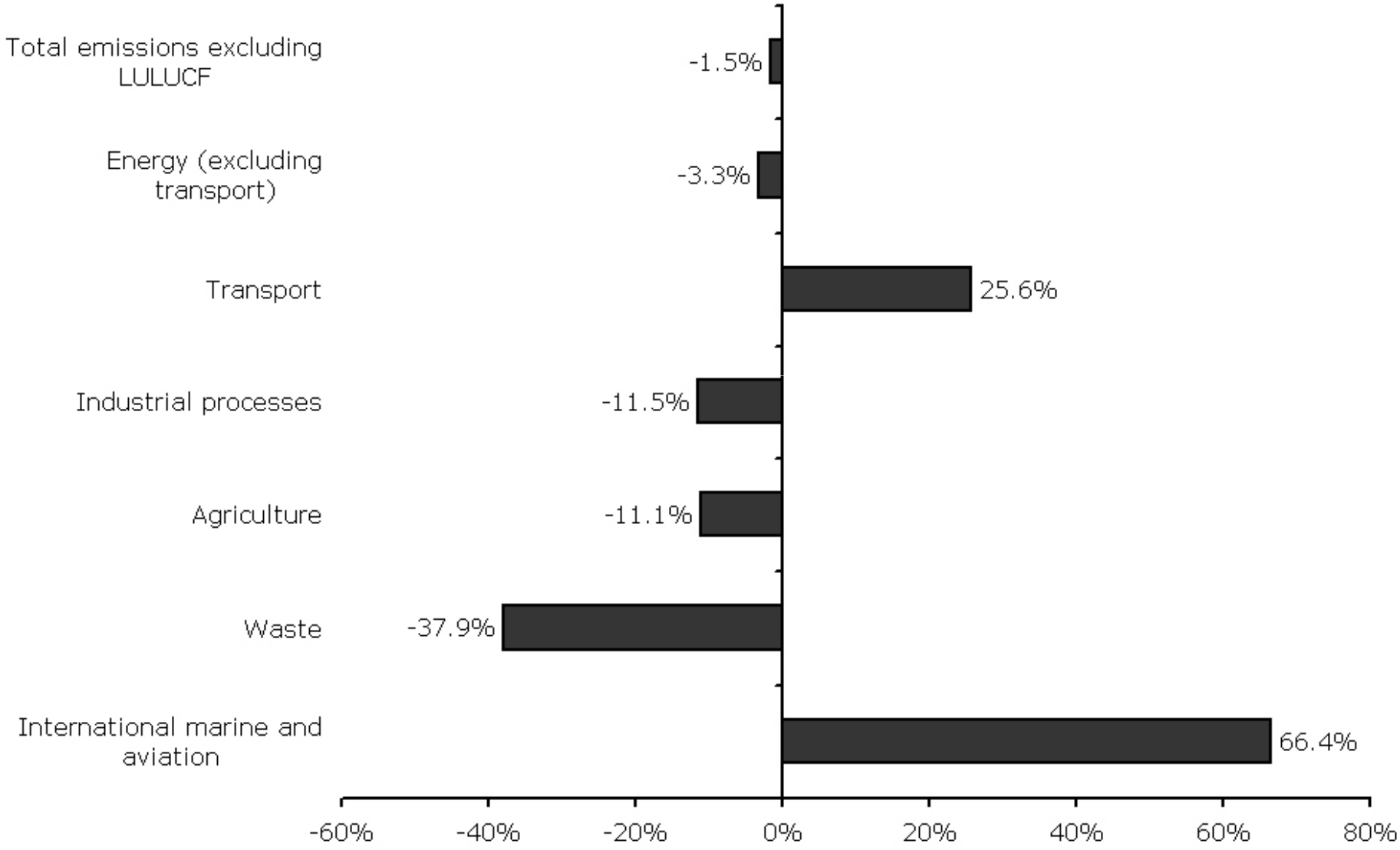
# Emission Growth in the EU-15 from 1990 to 2005



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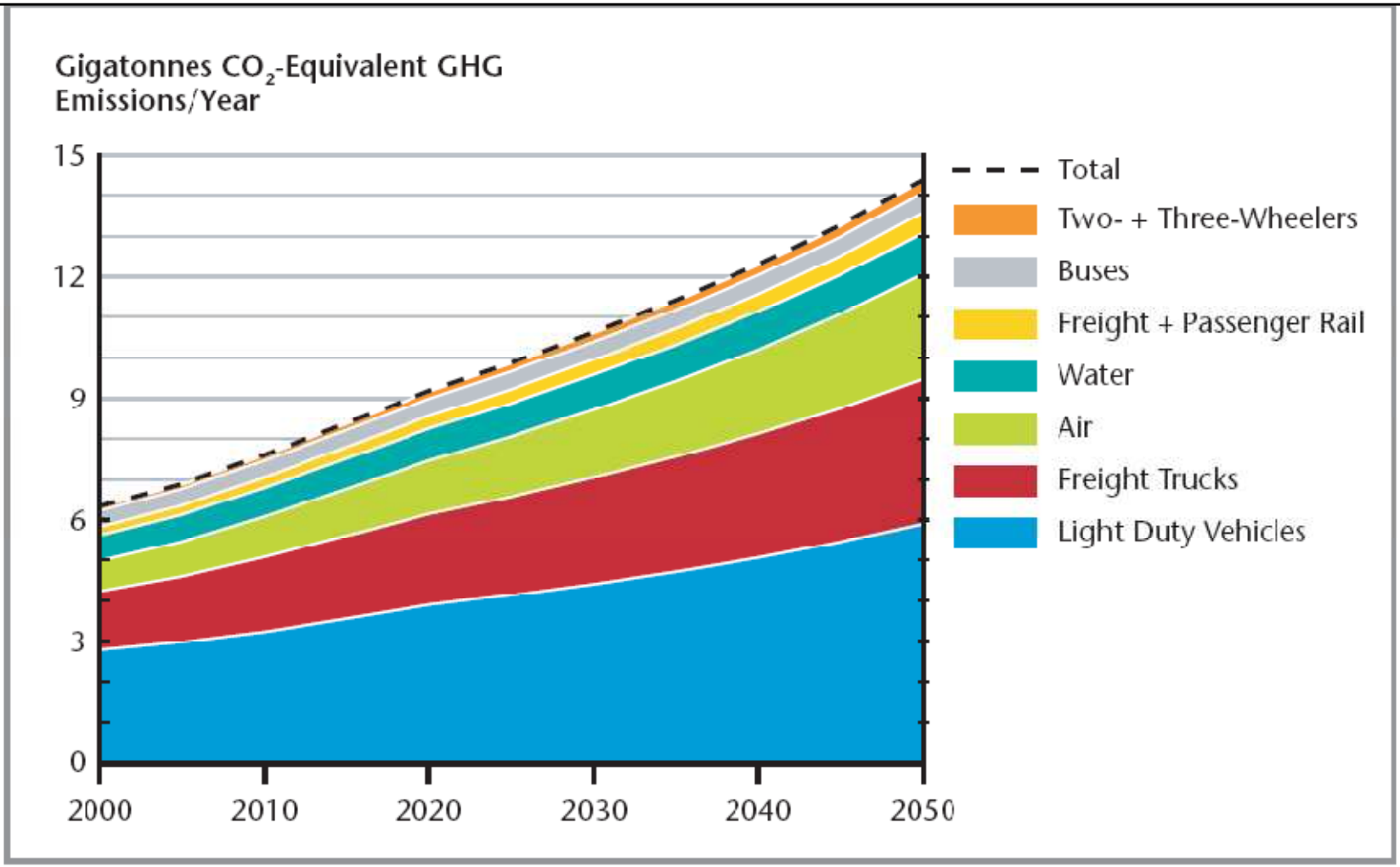
# $CO_2$-emissions Projection by Transport Modes




Source: Sustainable Mobility Project calculations.

# Introduction

- **To mitigate fuel demand and $CO_2$-emissions from passenger transport many countries introduced fuel economy regulations; the US have been the first with their Corporate Average Fuel Economy (CAFE) regulations**
- **The EU has announced to implement mandatory legislation in order to limit the average $CO_2$-emissions of new cars to 130 g $CO_2$ per km after targets of the voluntary commitments of the automobile industry to reduce the specific $CO_2$-emissions of passenger cars could not be achieved**
- **The study examines:**
  - **Why emission standards?**
  - **Uniform standards vs. weight based standards?**
  - **How to appraise the current EU legislation proposal**
  - **Is their an more efficient alternative: tradable emission standards?**

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**Conclusion**

# Why Emissions Standards?
# Economic Rationale of Vehicle Emission Standards

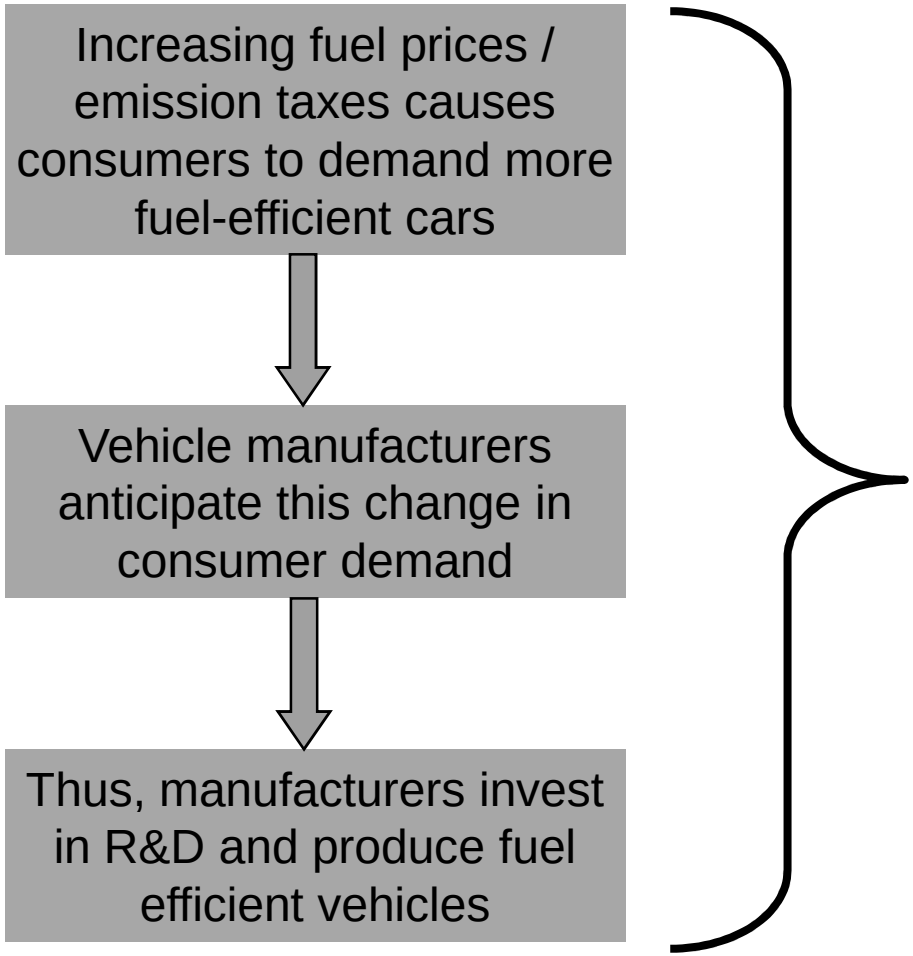
- **Vehicle emissions standards are a regulatory instrument that aims at**
  - Increasing fuel economy
  - Reduction of $CO_2$-emissions
  - Reduction of oil dependency

- **Vehicle emission standards are not capable of controlling absolute $CO_2$-emissions to several uncertainties (mileage, actual driving behavior, peripheral components, congestion, etc.)**

- **Under optimal market conditions transmitted price signals (fuel taxes/emissions taxes) facilitate the achievement of the desired efficiency targets**

- **If market fails in giving the right incentives, investments in R&D for cleaner technologies and the early implementation of low-carbon technologies may be procrastinated**
  - Procrastinated current investments increase the future marginal abatement cost
  - Suboptimal intertemporal abatement path

# Economic Rationale of Vehicle Emission Standards




Imperfect market conditions at each of these levels could impair the transmission of the price signals and may lead to suboptimal market results

# Economic Rationale of Vehicle Emission Standards

**Consumer:**

- Uncertainty about future fuel prices
- Myopic foresight
  - **Consumers make irrational decisions: consumers do not take future fuel costs appropriately into account**
- Excessive discount rates
  - **Consumers (even non-myopic ones) discount future fuel savings of efficient vehicles at higher rates than the socially optimal discount rate**
  - **lacking policy credibility impacts expectations on fuel prices, resale prices, etc.**

**Manufacturers**

- Uncertainty about future demand and prospective climate policy (credibility problem)
- Managers aim at short time profit maximization in order to increase own income instead of long-term optimization
- Spill-overs / positive externalities of innovations
  - **If know-how and resulting benefits of "green" innovations disperse without adequate compensation, such investments will be hampered**

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# Uniform vs. Weight-based Standards: Basic Model

- **Average emissions are to be reduced to a mandatory emission standard**
- **Average emissions are dependent on the vehicle weight and on the parameter "others" comprising all other determinants**
- **Reduction costs of a manufacturer i are a convex function of the <u>relative</u> changes in these parameters**

$$RC_i^t(\varphi_{i,w}^t, \varphi_{i,o}^t) \qquad \varphi_{i,w}^t = \frac{x_{i,w}^0 - x_{i,w}^t}{x_{i,w}^0} \qquad \varphi_{i,o}^t = \frac{x_{i,o}^0 - x_{i,o}^t}{x_{i,o}^0}$$

$$MRC_{i,o}^t = \frac{\partial RC_i^t(\varphi_{i,w}^t, \varphi_{i,o}^t)}{\partial \varphi_{i,o}^t} > 0 \qquad MRC_{i,w}^t = \frac{\partial RC_i^t(\varphi_{i,w}^t, \varphi_{i,o}^t)}{\partial \varphi_{i,w}^t} > 0$$

$$\frac{\partial MRC_{i,w}^t}{\partial \varphi_{i,w}^t} = \frac{\partial^2 RC_i^t(\varphi_{i,w}^t, \varphi_{i,o}^t)}{\partial (\varphi_{i,w}^t)^2} > 0 \qquad \frac{\partial MRC_{i,o}^t}{\partial \varphi_{i,o}^t} = \frac{\partial^2 RC_i^t(\varphi_{i,w}^t, \varphi_{i,o}^t)}{\partial (\varphi_{i,o}^t)^2} > 0$$

# Uniform vs. Weight-based Standards: Basic Model

**Emissions per vkm of manufacturer i in period t:**

$$E_i^t(x_{i,w}^t, x_{i,o}^t) = E_i^t\left(\left(x_{i,w}^0 - \varphi_{i,w}^t * x_{i,w}^0\right), \left(x_{i,o}^0 - \varphi_{i,o}^t * x_{i,o}^0\right)\right)$$

$$\frac{\partial E_i^t}{\partial \varphi_{i,w}^t} = -x_{i,w}^0 \cdot \frac{\partial E_i^t}{\partial\left(x_{i,w}^0 - \varphi_{i,w}^t \cdot x_{i,w}^0\right)}$$

$$\frac{\partial E_i^t}{\partial \varphi_{i,o}^t} = -x_{i,o}^0 \cdot \frac{\partial E_i^t}{\partial\left(x_{i,o}^0 - \varphi_{i,o}^t \cdot x_{i,o}^0\right)}$$

# Uniform vs. Weight-based Standards: Macroeconomic Optimum

**For a given emission standard the aggregate reduction costs of all manufacturers are to be minimized:**

$$\sum_{i} \min_{(\varphi_{i,w}^{t}, \varphi_{i,o}^{t}))} \sum_{i=1}^{n} \left( RC_i^t (\varphi_{i,w}^{t}, \varphi_{i,o}^{t}) \cdot MS_i \right)$$

**s.t.** $$\sum_{i=1}^{n} \left( E_i^t (x_{i,w}^{t}, x_{i,o}^{t}) \cdot MS_i \right) = \overline{E}^t$$

# Uniform vs. Weight-based Standards: Macroeconomic Optimum

**We get the following optimum conditions:**

**1)**
$$\frac{MRC^{t}_{i,w} \cdot \frac{1}{x^{0}_{i,w}}}{\frac{\partial E^{t}_{1}}{\partial\left(x^{0}_{i,w} - \varphi^{t}_{i,w} \cdot x^{0}_{i,w}\right)}} = \frac{MRC^{t}_{j,w} \cdot \frac{1}{x^{0}_{j,w}}}{\frac{\partial E^{t}_{1}}{\partial\left(x^{0}_{j,w} - \varphi^{t}_{j,w} \cdot x^{0}_{j,w}\right)}} \quad \forall i,\ j = 1,\ldots,n$$

**2)**
$$\frac{MRC^{t}_{i,w} \cdot \frac{1}{x^{0}_{i,o}}}{\frac{\partial E^{t}_{1}}{\partial\left(x^{0}_{i,o} - \varphi^{t}_{i,o} \cdot x^{0}_{i,o}\right)}} = \frac{MRC^{t}_{j,o} \cdot \frac{1}{x^{0}_{j,o}}}{\frac{\partial E^{t}_{1}}{\partial\left(x^{0}_{j,o} - \varphi^{t}_{j,o} \cdot x^{0}_{j,o}\right)}} \quad \forall i,\ j = 1,\ldots,n$$

**3)**
$$\frac{MRC^{t}_{i,w} \cdot \frac{1}{x^{0}_{i,w}}}{\frac{\partial E^{t}_{i}}{\partial\left(x^{0}_{i,w} - \varphi^{t}_{i,w} \cdot x^{0}_{i,w}\right)}} = \frac{MRC^{t}_{i,w} \cdot \frac{1}{x^{0}_{i,o}}}{\frac{\partial E^{t}_{1}}{\partial\left(x^{0}_{i,o} - \varphi^{t}_{i,o} \cdot x^{0}_{i,o}\right)}} \quad \forall i = 1,\cdots,n$$

# Uniform vs. Weight-based Standards: Macroeconomic Optimum

**This can be simplified to the well-known optimum conditions:**

$$\frac{MRC_{i,w}^{t} \cdot \frac{1}{x_{i,w}^{0}}}{\frac{\partial E_1^t}{\partial\left(x_{i,w}^{0} - \varphi_{i,w}^{t} \cdot x_{i,w}^{0}\right)}} = MAC_{i,w}^{t} \qquad \frac{MRC_{i,o}^{t} \cdot \frac{1}{x_{i,o}^{0}}}{\frac{\partial E_1^t}{\partial\left(x_{i,o}^{0} - \varphi_{i,o}^{t} \cdot x_{i,o}^{0}\right)}} = MAC_{i,o}^{t}$$

**1)** $MAC_{i,w}^{t} = MAC_{j,w}^{t} \forall i, j = 1, \ldots, n$

**2)** $MAC_{i,o}^{t} = MAC_{j,o}^{t} \forall i, j = 1, \ldots, n$

**3)** $MAC_{i,w}^{t} = MAC_{i,o}^{t}$

# Uniform vs. Weight-based Standards: Weight-based Standards

**A weight-based standard defines manufacturer-specific emission targets according to the average weight of the manufacturers vehicles.**

**Definition of the weight-based standard:**

$$\overline{E}_i^t = \overline{E}^t + \alpha_w \left( x_{i,w}^t - \sum_{j=1}^{n} \left( x_{i,w}^t * MS_i \right) \right)$$

**$\alpha_w$: Impact of vehicle weight on the manufacturer-specific standard**

**$MS_i$: Market share of manufacturer i**

# Uniform vs. Weight-based Standards: Weight-based Standards

**A single manufacturer is facing the following optimization problem:**

$$\min_{\varphi_{i,w}^t, \varphi_{i,o}^t} RC_i^t(\varphi_{i,w}^t, \varphi_{i,o}^t)$$

**s.t.** $$E_i^t(x_{i,w}^t, x_{i,o}^t) = \overline{E}^t + \alpha_w \left( x_{i,w}^t - \sum_{i=1}^{n} \left( x_{i,w}^t * MS_i \right) \right)$$

# Uniform vs. Weight-based Standards: Weight-based Standards

**Minimizing its compliance costs, each manufacturer will choose its reduction efforts according to:**

$$\frac{MRC_{i,o}^{t} \cdot \frac{1}{x_{i,o}^{0}}}{\frac{\partial E_i^t}{\partial\left(x_{i,o}^{0} - \varphi_{i,o}^{t} \cdot x_{i,o}^{0}\right)}} = \frac{MRC_{i,w}^{t} \cdot \frac{1}{x_{i,w}^{0}}}{\left(\frac{\partial E_i^t}{\partial\left(x_{i,w}^{0} - \varphi_{i,w}^{t} \cdot x_{i,w}^{0}\right)} - \alpha_w \cdot \left(1 - MS_i\right)\right)}$$

$$\Rightarrow \frac{MRC_{i,o}^{t} \cdot \frac{1}{x_{i,o}^{0}}}{\frac{\partial E_i^t}{\partial\left(x_{i,o}^{0} - \varphi_{i,o}^{t} \cdot x_{i,o}^{0}\right)}} = \frac{MRC_{i,w}^{t} \cdot \frac{1}{x_{i,w}^{0}}}{\frac{\partial E_i^t}{\partial\left(x_{i,w}^{0} - \varphi_{i,w}^{t} \cdot x_{i,w}^{0}\right)}} \cdot \frac{\frac{\partial E_i^t}{\partial\left(x_{i,w}^{0} - \varphi_{i,w}^{t} \cdot x_{i,w}^{0}\right)}}{\left(\frac{\partial E_i^t}{\partial\left(x_{i,w}^{0} - \varphi_{i,w}^{t} \cdot x_{i,w}^{0}\right)} - \alpha_w \cdot \left(1 - MS_i\right)\right)}$$

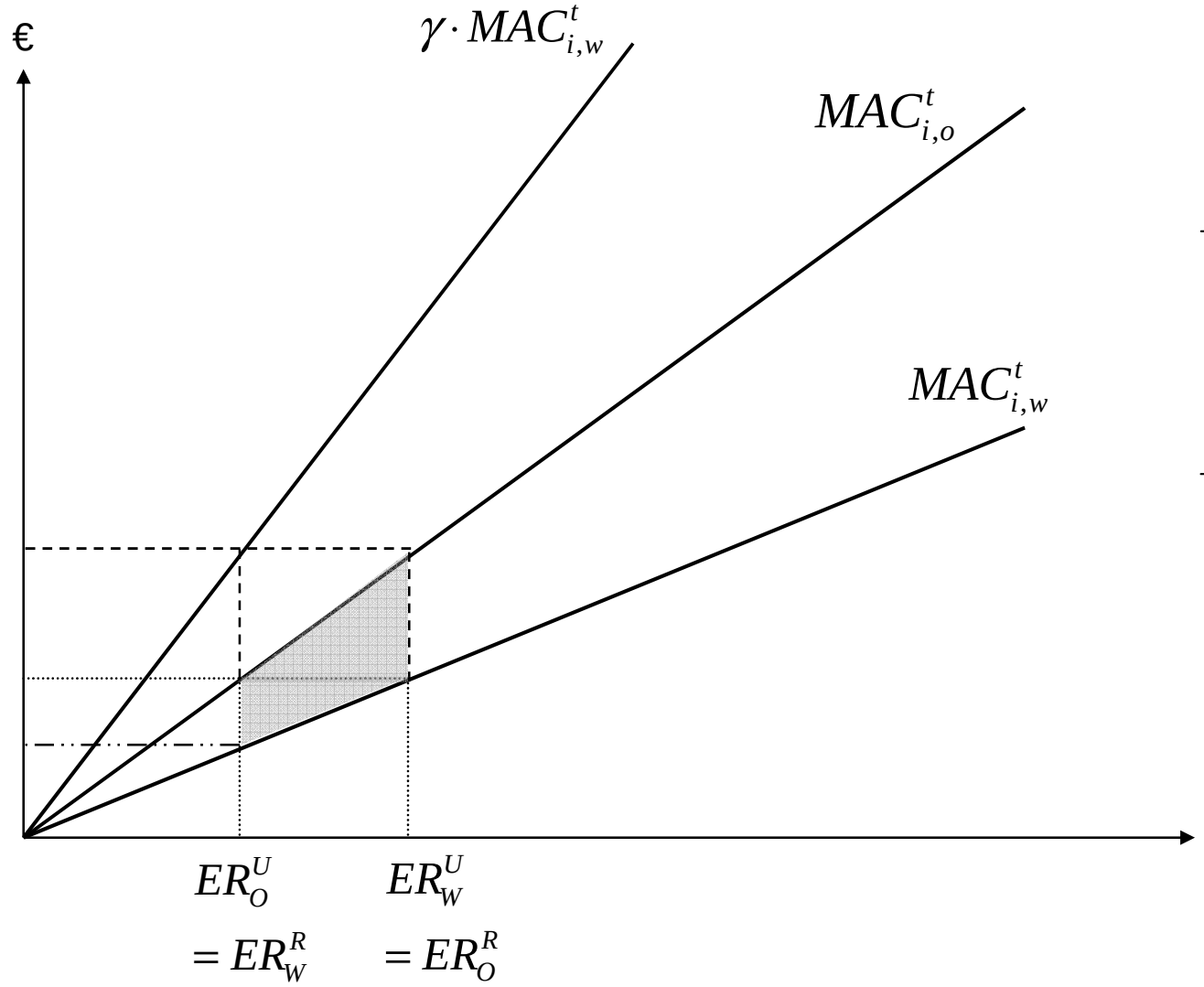
# Uniform vs. Weight-based Standards: Weight-based Standards

$$MAC_{i,o}^{t} = MAC_{i,w}^{t} \cdot \gamma$$

$$\gamma = \frac{\frac{\partial E_i^t}{\partial\left(x_{i,w}^0 - \varphi_{i,w}^t \cdot x_{i,w}^0\right)}}{\left(\frac{\partial E_i^t}{\partial\left(x_{i,w}^0 - \varphi_{i,w}^t \cdot x_{i,w}^0\right)} - \alpha_w \cdot \left(1 - MS_i\right)\right)}$$

**Obviously, optimum condition 3) is violated: Weight reduction as a means of emission mitigation is used to a smaller extent than optimal, and vice versa**

# Uniform vs. Weight-based Standards: Weight-based Standards




$$\frac{MAC_O(ER_O^U)}{MAC_W(ER_W^U)} = 1$$

$$\frac{MAC_O(ER_O^R)}{MAC_W(ER_W^R)} = \gamma$$

# Uniform vs. Weight-based Standards: Weight-based Standards

**Assuming linear MAC functions, the shift in the reduction efforts can be calculated as follows:**

$$\Delta ER_W = \Delta ER_O = ER \cdot \left( \frac{1}{1 + \frac{\left( \frac{\partial MAC^t_{i,o}}{\partial ER_O} \right)}{\gamma \cdot \left( \frac{\partial MAC^t_{i,w}}{\partial ER_W} \right)}} - \frac{1}{1 + \frac{\left( \frac{\partial MAC^t_{i,o}}{\partial ER_O} \right)}{\left( \frac{\partial MAC^t_{i,w}}{\partial ER_W} \right)}} \right)$$

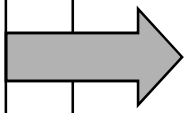
**The more similar the slopes of the MAC functions, the greater the shift in emission reduction efforts between weight reduction and "others"**

**The greater the slope of the MAC for reduction of "others" compared to weight reduction, the greater the welfare loss per shifted unit of emission reduction**

# Uniform vs. Weight-based Standards: Weight-based Standards

**However, they are also some merits of weight-based standards:**

- **Although, uniform standards comply with optimum condition 3), i.e. equal MAC of both reduction options, they are still inefficient compared to the macroeconomic optimum.**
- **The macroeconomic optimum requires equalized MAC between all manufacturers.**
- **In a heterogenic market, different manufacturers have different initial emissions and therefore different MAC for achieving a uniform standard.**
- **Weight-based standards make allowances for such differences and can thus mitigate these MAC differences between manufacturers**



**Trade-off between two kinds of inefficiencies!**

# Uniform vs. Weight-based Standards: Essential Results

- **In general, both approaches violate the conditions for a first-best solution**
  - MAC of weight reduction = MAC of adjustments of „others“
  - Equality of MAC across all manufacturers

- **Uniform standards impose excessive reduction costs on manufacturers of heavy vehicles, because they have to focus – in the short term – on adjustments of “others”**

→ **Favorability of weight-based standards as the differentiate individual reduction targets**

→ **Mitigation of the gap in the MAC of different manufacturers**

- **Weight-based standards bias the decision between the different abatement options: Weight reduction becomes relatively unattractive**

→ **The MAC of adjustment of “others” exceed the MAC of weight reduction**

→ **Suboptimal fleet structure: vehicles are too heavy**

# Uniform vs. Weight-based Standards: Time dependency

**• The drawbacks of weight-based standards gain relevance with the importance of weight reduction as a means of emission reduction, i.e. with decreasing costs of weight reduction.**

**•Short-term: costs for weight reduction are relatively high**

- Fleet restructuring requires time
- 5-7 years development period for new models

**• Long-term: weight reduction becomes relatively cheaper**

- Scope for fleet restructuring and model variations
- Changing consumer preferences (raising public awareness, advertisement, etc.)

**→ Undesired incentives of weight-based standards become evident particularly in the long-run**

**• Favorability of either uniform standards or weight-based standards is time-dependent: The longer the regarded time scale, the greater the cumulated relative efficiency losses of weight-based standards**

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**Economic Rationale of Vehicle Emission Standards**

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# Implications for Europe

**Proposal of the EU Commission (19 December 2007)**

- **After failure of the voluntary agreements of ACEA, JAMA, KAMA, mandatory legislation on vehicles' $CO_2$-emissions was announced**
- **Car manufacturers have to achieve 130 g $CO_2$ / km by 2012 through improvements of engine technology only (additional reduction of 10 g $CO_2$ / km through further measures)**
- **Manufacturer-specific targets based on average weight of the fleet**

  **$CO_2 = 130 + 0{,}0457 \times (M - M_0)$**

  **M: Vehicle weight in in kg**

  **$M_0$: 1289 kg (current average weightin the EU) × f**

  **f: Adjustment parameter to consider changes in the average vehicle weight**
- **Penalties per g exceeding the target: 20 € (2012), 35 € (2013), 60 € (2014), 95 € (2015)**
- **Manufacturers can form a pool in order to comply jointly with the regulations**

# Implications for Europe

**Assessment of the Proposal**

- **Actual trendline is steeper than the limit value Limit value curve:**

  **The granted additional emissions per 100 kg vehicle weight (4.57 g $CO_2$ / km) are less than the corresponding physically induced emissions increase (~ 10 g $CO_2$ / km)**

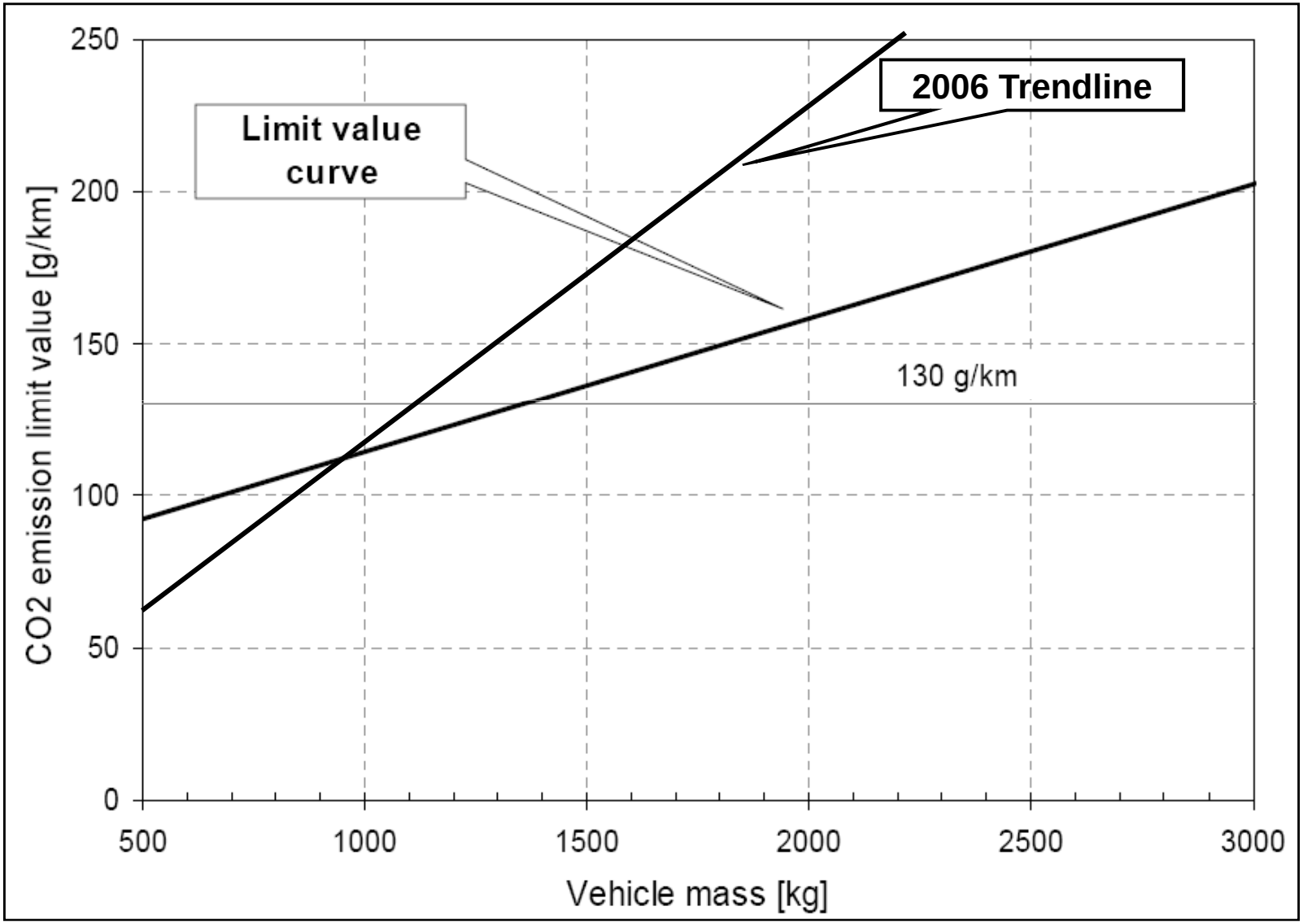
- **Abatement options other than weight reduction will be used to extent exceeding the optimum:**

  **Theory suggests that in the equilibrium marginal abatement costs of these options will be almost double of the marginal abatement costs of weight reduction**

- **Current proposal is the result of a bargaining process between French/Italian interests on the one side and German interest on the other side, who would benefit from uniform standards and a tighter link between vehicle weight and specific targets respectively.**

- **Pooling option allows a rudimentary form of emissions trading, but why not being consequent and setting up a scheme of tradable emission credits in order improve the efficiency of the regulation?**

# Limit Value curve of the EU-proposal and actual Trendline



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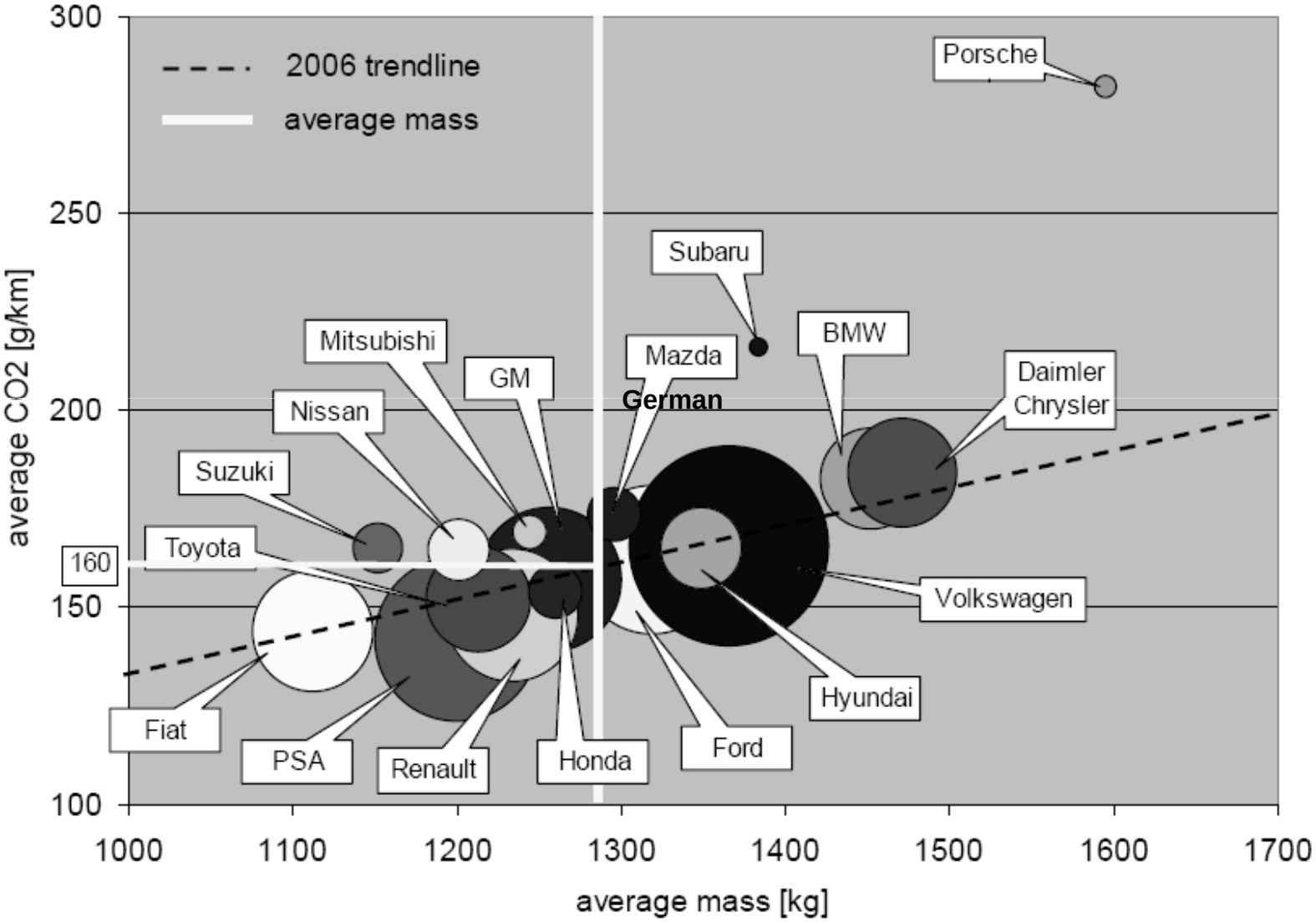
# $CO_2$-emissions of European Manufacturers in 2006



# Required Emission Reductions to Achieve the EU Target

| | |
|---|---|
| PSA Peugeot-Citroen | 16 |
| Renault | 20 |
| Fiat | 22 |
| Honda | 25 |
| Toyota | 25 |
| GM | 28 |
| Ford | 30 |
| Volkswagen | 31 |
| Hyundai | 32 |
| Nissan | 38 |
| Suzuki | 41 |
| Mitsubishi | 41 |
| Mazda | 43 |
| BMW | 45 |
| DaimlerChrysler | 46 |
| Subaru | 81 |
| Porsche | 138 |

- **In average, European manufacturers have to cut their specific emissions by 29 g $CO_2$ / vkm.**

- **There are great disparaties between the individual reduction requirements of individual manufacturers**

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# Tradable Vehicle Emission Standards

- **Tradable vehicle emissions standards can overcome the disadvantages of both uniform and reference parameter based standards.**
- **They are a least cost solution if**
  - A manufacturer's individual baseline is independent of current values of a reference parameter
  - The credit market is competitive
- **Emission credits are generated by manufacturers undercutting the respective baseline**
- **Manufacturers with average $CO_2$-emissions per km above the standard can buy credits from manufacturers emitting below the standard**
- **All manufacturers will adjust their fleets until their marginal abatements costs equal the credit price**
- **Continuous incentives efficiency improvements of the fleet as manufacturers benefit from emission reductions in the form of credit revenues**

# Tradable Vehicle Emission Standards

- **Distributive effects depend on the baseline definition**
  - In order to prevent lopsided financial burdens, initial credit endowments could be based on past emissions values or past reference parameter values (grandfathering)

- **Small number of actors in the credit market facilitates the risk of strategic behavior**
  - A guaranteed lower and an upper boundary (“safety valve”) of the credit price ensures incentives for continuous efficiency improvements and mitigates the risk of market power abuse in the credit market
  - Alternatively a semi-open link to an ETS could be established
  - A full link is difficult to realize as the absolute amount of $CO_2$-emissions cannot be controlled accurately by means of vehicle emissions standards

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# Conclusions

- **In case of market failures in the reaction to price signals (myopic foresight, excessive discount rates, etc.) vehicle emission standards are an effective means of improving the efficiency of passenger cars**
- **Uniform standards do not take account of differing marginal abatement costs between inhomogeneous manufacturers**
- **Reference parameter based standards bias the decision between different abatement options**
- **Trade-off between short-run and long-run efficiency: time dependency**
- **In particular weight-based standards are inefficient in the long-run as weight reduction is one of the most powerful means for reducing vehicle emissions**
  - CAFE regulations have lead to reduced MPG, i.e. higher $CO_2$-emissions per km, due to higher market shares of SUV
- **Tradable vehicle emissions standards are capable of achieving a given standard at least cost**
- **The EU could address undesired distributive effects of a scheme of tradable emission standards through differentiated initial credit endowments**

# The End…

# Thank you very much for your attention!