Fuel Economy Improvements of Swiss and European New Passenger Cars

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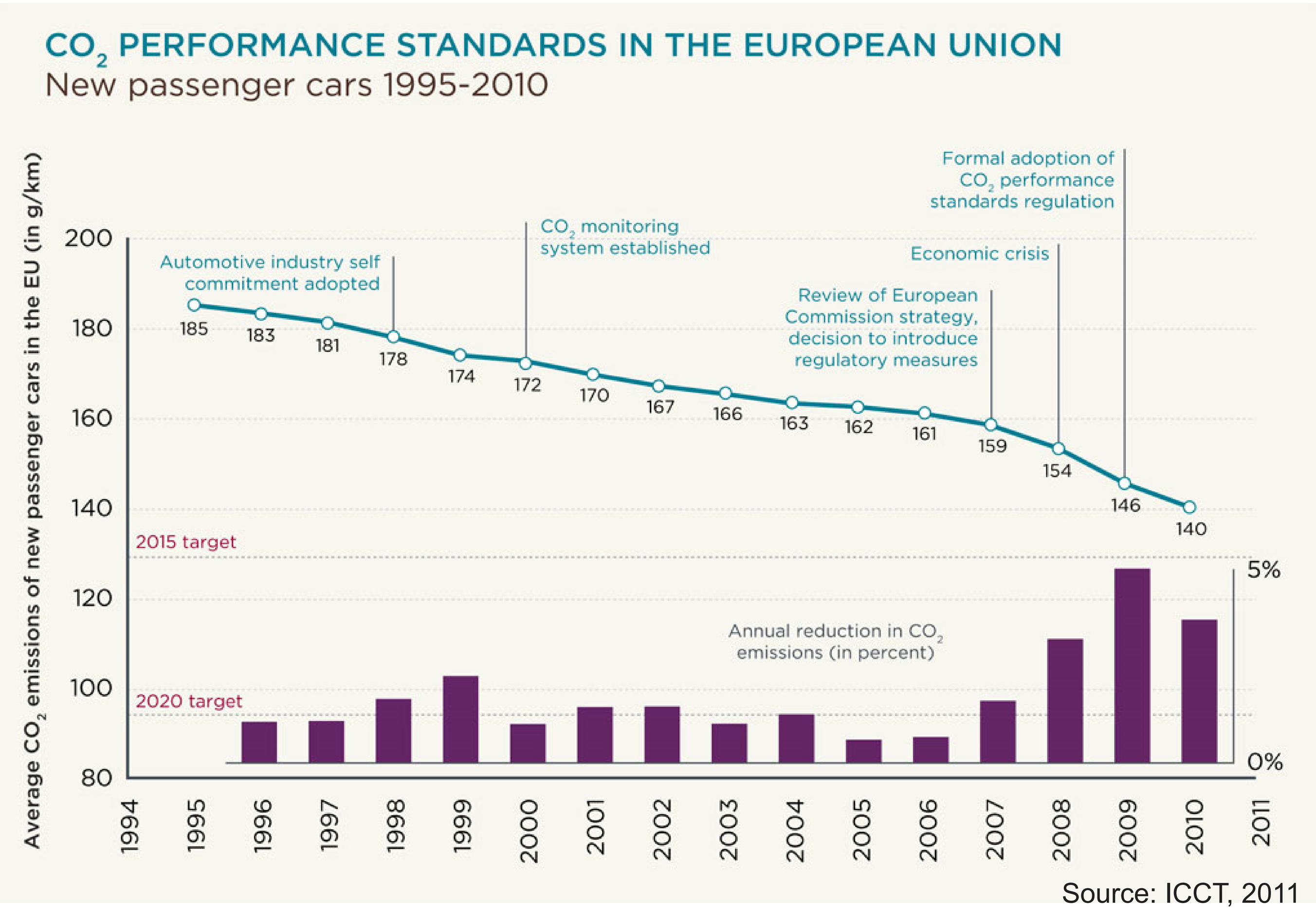
Introduction

Swiss and European Trends



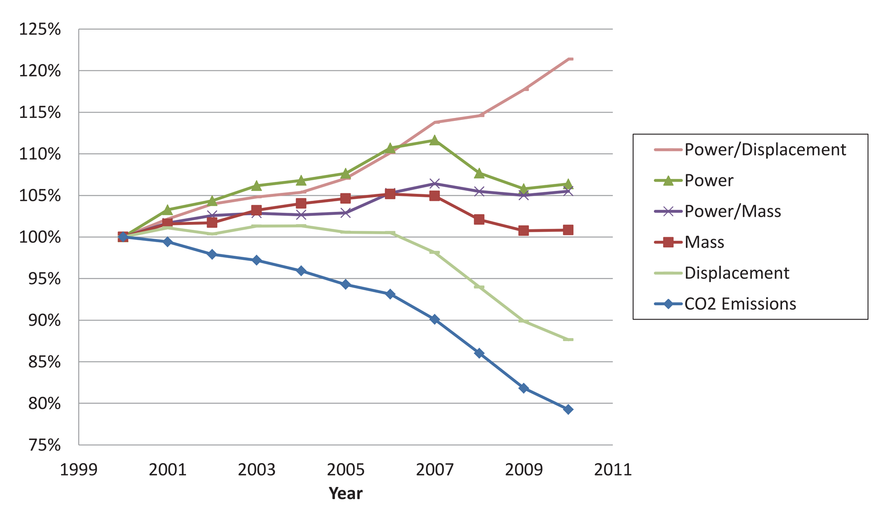
Source: ICCT, 2011

- Passenger cars contribute about 12% to total CO_2 emissions in Europe and one third in Switzerland. As part of the EU strategy to reduce CO_2 emissions, a legislation has been ratified limiting CO_2 emissions to an average of 130 g/km by 2015 and to 95 g/km by 2020. This policy has recently been adopted in Switzerland.
- From 2000 to 2010, CO_2 emissions from new passenger cars as measured on the New European Driving Cycle (NEDC) continuously declined from 172 g/km to 140 g/km in Europe and from 200 g/km to 161 g/km in Switzerland. This reduction was achieved by continuous incremental powertrain efficiency improvements, reductions of vehicle resistances, and a shift of sales from gasoline to diesel. This trend was opposed by an increase of average weight and acceleration performance.
- This work investigates the competing influences of weight, performance, and engine size on CO_2 emissions. It analyzes the effect of engine downsizing, and to which extent it has been offset by an increase of acceleration performance. It identifies the temporal evolution of vehicle efficiency improvements independent of the increase in weight and performance and correlates them with the introduction of the EU emission standard.

Objectives and Methodology

Objectives of Research

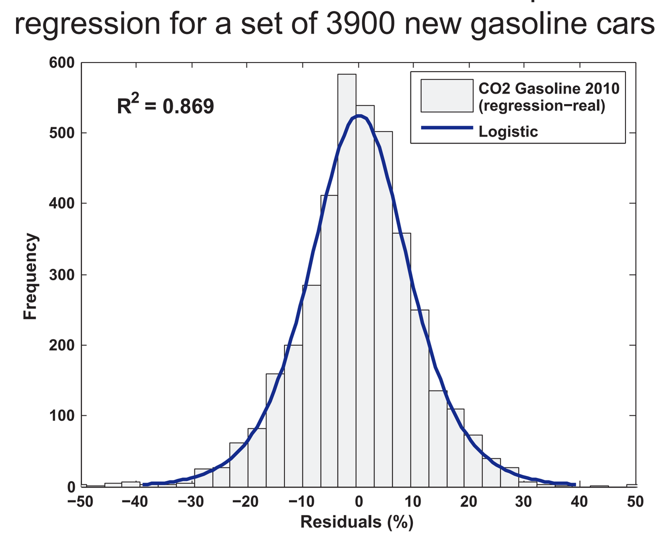
- Assessment of the competing influences of weight, performance, and engine size on new vehicles CO_2 emission.
- Analysis of fleet aggregated historic trends to attribute CO_2 reduction effects, as well as to determine potential additional reductions at constant performance and mass.
- Correlation of efficiency improvements with the introduction of the EU emission standard and changes in consumer criteria to fuel prices.



Methodology

- Decoupling of the main drivers of fuel consumption based on physical considerations of mechanical energy demand.
- Regression analysis with respect to selected independent parameters. Multiple linear regression reveals that the mass, power to mass, and the power to displacement ratio are important quantities for predicting CO_2 emissions. The power to displacement ratio is especially good as an engine-specific measure.

Distribution of residuals found in multiple linear regression for a set of 3900 new gasoline cars

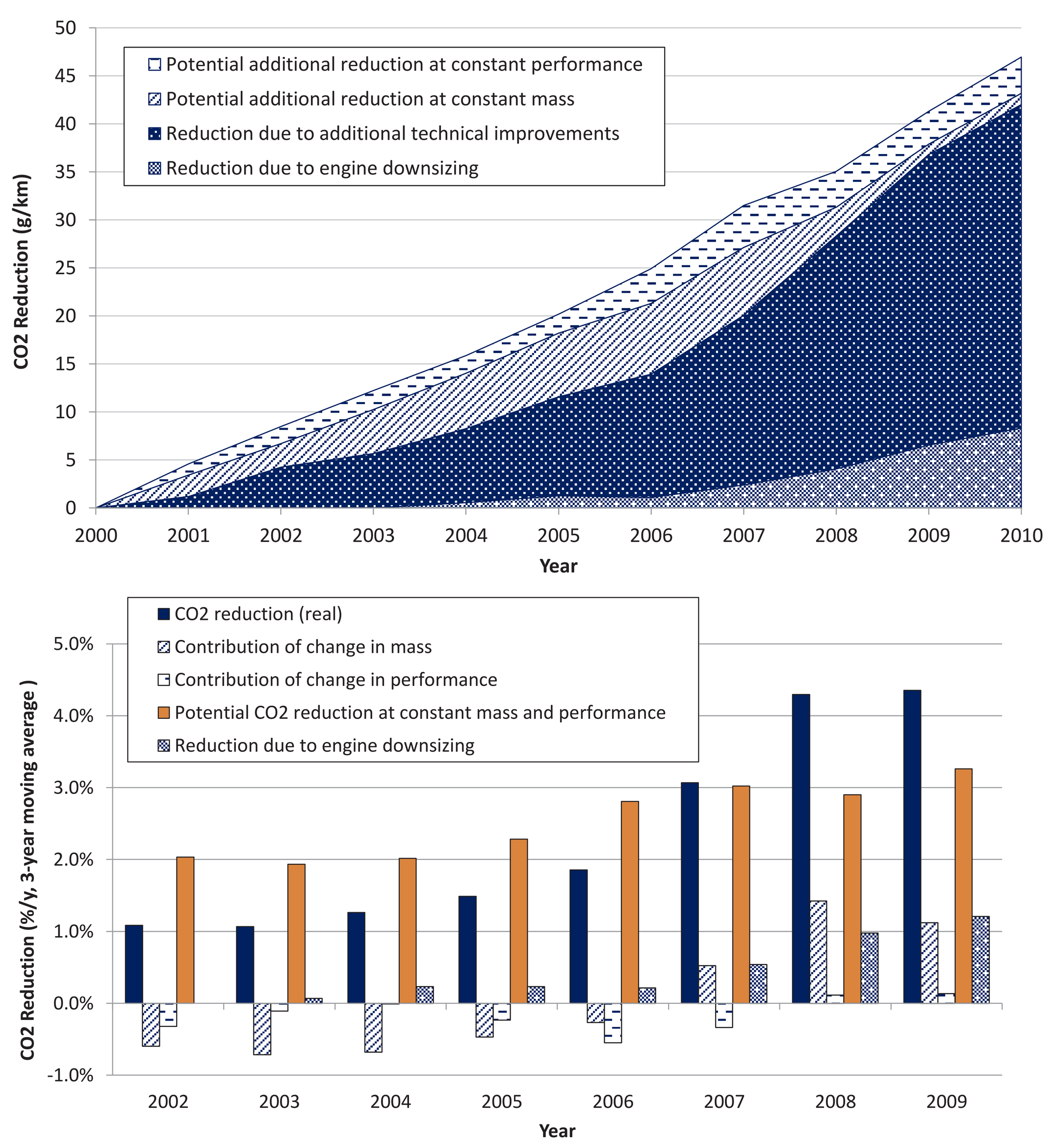


Dependence of new gasoline vehicle CO_2 emission on the mass, power to mass, and/or power to displacement ratio found in four different linear regression models.

Independent variables	$\frac{\partial CO_2}{\partial m}$	$\frac{\partial CO_2}{\partial (\frac{P}{m})}$	$\frac{\partial CO_2}{\partial (\frac{P}{D})}$	$\frac{\partial CO_2}{\partial (\frac{D}{m})}$	R^2
m	0.149 $\frac{g}{kg}$	—	—	—	0.644
$m, P/m$	0.107 $\frac{g}{kg}$	712 ($\frac{g}{kW}$)/kg	—	—	0.818
$m, P/m, P/D$	0.107 $\frac{g}{kg}$	938 ($\frac{g}{kW}$)/kg	-1189 g/($\frac{kW}{cm^3}$)	—	0.869
$m, D/m$	0.107 $\frac{g}{kg}$	—	—	60.9 g/($\frac{cm^3}{kg}$)	0.855

Results and Discussion

Attribution of Effective and Potential CO_2 Reductions



Swiss Gasoline Cars from 2000 to 2010:

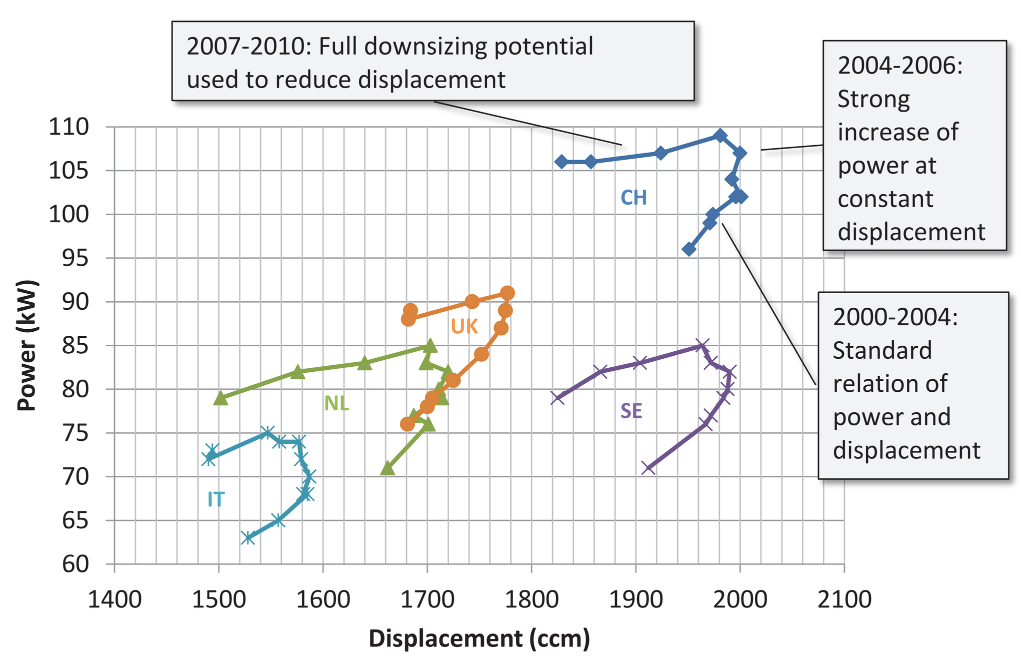
- Effective CO_2 reductions increased from ca. 1%/y to 4%/y, and potential CO_2 reductions at constant mass and performance from ca. 2%/y in the first half to 3%/y in the second half of the decade.
- Until 2006 increases in vehicle weight and to minor extent in performance opposed actual vehicle efficiency improvements. This reversed from 2006 to 2009, in part caused by consumer sensitivity to rising fuel prices.
- We find that most of the increase of the efficiency potential is due to the enhanced sales share of vehicles with downsized engines. From 2006 to 2010, engine downsizing contributed to about 8 g/km to total CO_2 reductions.

Conclusion and Outlook

- This work presents a new methodology to analyse the influence sales aggregated vehicle characteristics on fuel consumption and CO_2 emission. It enables the attribution of past effective and potential CO_2 reduction effects.
- The analysis of Swiss gasoline vehicles reveals a continuous increase of the efficiency potential over the last decade together with an enhanced use of engine downsizing after 2006. These findings suggest that the rising pressure on the EU car industry to improve efficiency has indeed been effective.
- The methodology presented here can be used for temporally resolved analysis of efficiency improvements and hence assist in assessing the effectiveness of emission standards. It can be applied to data from individual manufacturers, countries, or vehicle segments.
- It also helps to identify the main influences on future fleet CO_2 emission and to compare high penetration technology advance vs. more radical technology that will only gradually gain market share.

Trends in Engine Downsizing

- Engine downsizing with turbocharging is a strategy currently pursued by manufacturers to improve efficiency. Refers to reduction of displacement at constant performance and enables decrease of engine operation at partial loads. It is accompanied by an increase of specific power, i.e. the power to displacement ratio.
- Recent development in Europe is characterized by three phases: a standard increase of power with displacement (2000 to 2004), strong increase of specific power after 2004, which was first used to boost average power at constant displacement (2004-2006), and only after 2006 used to reduce displacement.



References

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