Summary

Vehicle age and crash risk

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The aim of the present study was to investigate the effects of improved vehicle safety and increased vehicle weight among passenger cars over time. Poisson regression models were developed of injury crashes involving passenger cars in Norway during 2000-2016, with the cars' (in models for car-car collisions additionally the crash partners) first year of registration and weight as predictor variables. Crash year and the drivers age and gender were statistically controlled for. Passenger cars from later registration years were found to have fewer and less serious crashes than cars from earlier registration years. On average, it is estimated that there are 4.2% fewer killed or seriously injured (KSI) drivers in cars from any registration year X than in cars from the preceding registration year, if the cars weight is held constant. In cars from model year 2014-2016 there are on average 72% fewer KSI drivers than in cars from 1980-1990. Safety improvements have been somewhat larger in lighter cars than in heavier cars. Crashes with heavier cars are on average less serious for the driver of the car, but more serious for crash partners (other car drivers or pedestrians/cyclists). Older cars have on average more and more serious crashes than newer cars if registration year and crash year are held constant. Hypothetically, if the whole current Norwegian passenger car fleet were replaced by new cars, the number of KSI car drivers would be reduced by 30%. By increasing the renewal rate of the passenger car fleet, the number of KSI car driver would be halved (compared to 2015) in 2039 instead of in 2045.

This report presents an investigation of the effect of passenger cars' year of first registration and weight on crash involvement (personal injury crashes, PIC), on the number of killed or seriously injured (KSI) car drivers, and on crash severity (KSI/PIC) for drivers of passenger cars. Effects of registration year and weight on a cars' aggressivity were investigated as well, i.e. the effects of the crash partners registration year and weight in car-car collisions on the driver of the own car and the effects of the own cars registration year and weight on injuries among pedestrians and cyclists. Table S.1 gives an overview of the results, including results for the drivers age and gender that were statistically controlled for. Crash year is statistically controlled for as well.

Table S.1: Overview of results (adjusted effects).

	Own risk[1]	Aggressivity[2]: Pedestrians/cyclists	Aggressivity[2]: Crash partner (driver) in car-car collisions
Year of first registration: Later registration years …	☺ **Fewer crashes** (KSI and PIC)**: Larger effect in lighter cars** ☺ **Lower crash severity** (KSI/PIC)**: Largest effect in car-car collisions**	☺ **Fewer and less serious crashes** (KSI, PIC, and KSI/PIC)	☺ **Fewer crashes** (KSI and PIC) 😐 No effect on crash severity (KSI/PIC)
Weight: Heavier cars …	☺ **Fewer and less serious crashes** (KSI and KSI/PIC)**: Largest effect in car-car collisions, no effect in single vehicle crashes** 😐 No effect on crashes (PIC)	☹ **More and more serious crashes** (KSI, PIC, and KSI/PIC)	☹ **More serious crashes and** (KSI and KSI/PIC) ☺ **Fewer crashes** (PIC)
Age: Older cars …	☹ **More and more serious crashes** (KSI, PIC, and KSI/PIC)	(no results)	(no results)
Driver: Young men …	☹ **More and more serious crashes** (KSI, PIC, and KSI/PIC)**: Largest effect in single vehicle crashes**	☹ **More and more serious crashes** (KSI, PIC, and KSI/PIC)	(no results)

[1]Risk for driver (own car). [2]Risk for crash partner (car driver in car-car collisions; ped./cycl. in collisions with ped./cycl.).

The results are based on Poisson regression models with PIC or KSI (car drivers or pedestrians/cyclists) as the dependent variable. Predictor variables are the cars' year of first registration and weight, crash year, the drivers' age and gender, and exposure (vehicle kilometers or PIC in models for KSI; vehicle kilometers in models for PIC). Models were developed for all crashes, single vehicle crashes, car-car collisions, and collisions with pedestrians or cyclists. In car-car collisions, the crash partners' registration year and weight are additional predictor variables. An overview of dependent and predictor variables is given in table S.2.

Table S.2: Overview of predictor and dependent variables.

	Explanation
Dependent variables	
Personal injury crashes: PIC	Models with vehicle kilometers as exposure: ▪ Number of PIC with passenger cars involved.
Serious crashes: KSI	Models with vehicle kilometers as exposure: ▪ KSI car drivers (models for all crashes, single vehicle crashes, and car-car collisions) ▪ KSI pedestrians/cyclists (models for collisions with pedestrians/cyclists).
Injury severity: KSI/PIC	Models with PIC as exposure: ▪ KSI car drivers (models for all crashes, single vehicle crashes, and car-car collisions) ▪ KSI pedestrians/cyclists (models for collisions with pedestrians/cyclists).
Predictor variables	
Registration year (own car)	10 groups: Pre 1980, 1980-1990 (reference), 1991-1995, 1996-2000, 2001-2003, 2004-2006, 2007-2009, 2010-2011, 2012-2013, 2014-2016.
Weight (own car)	Four groups: 0-1199 kg, 1200-1399 kg, 1400-1599 kg, 1600+ kg.
Crash partners registration year and weight	Same as for own car.
Drivers age and gender	Men and women, four age groups each: 18-24, 25-44, 45-65, 65+ years.
Crash year	Year in which crash occurred (2000-2016).
Exposure	Vehicle kilometers (millions) or PIC: ▪ Vehicle km: Model results refer to KSI or PIC per million vehicle km ▪ PIC: Model results refer to crash severity, i.e. the number of KSI per PIC.

The unit of analysis in the models for all crashes, single vehicle crashes, and pedestrian/bicycle collisions is a cohort of cars from registration year A (10 groups), in weight class B (four weight classes), with a driver in group C (eight groups according to age and gender), in crash year D (years 2000-2016). In the models for car-car collisions, the data are additionally grouped according to the crash partners registration year and weight. For each unit of analysis and each type of crash, the numbers of KSI and PIC has been retrieved from official injury crash statistics. The total number of vehicle kilometers has been estimated based on a cohort model of the national car fleet in which annual mileage for cars of different years of first registration and weight were calculated based on odometer readings from the registry of periodic vehicle inspection.

Registration year and own risk: Fewer and less serious crashes with cars from later years

Own risk refers to the risk a car driver is exposed to as a function of characteristics of the own car. Figure S.1 shows the estimated effects of registration year on KSI, PIC, and KSI/PIC in the different types of crashes, both for registration years 2014-2016 in comparison to registration years 1980-1990 and as average annual changes from any registration year to the next.

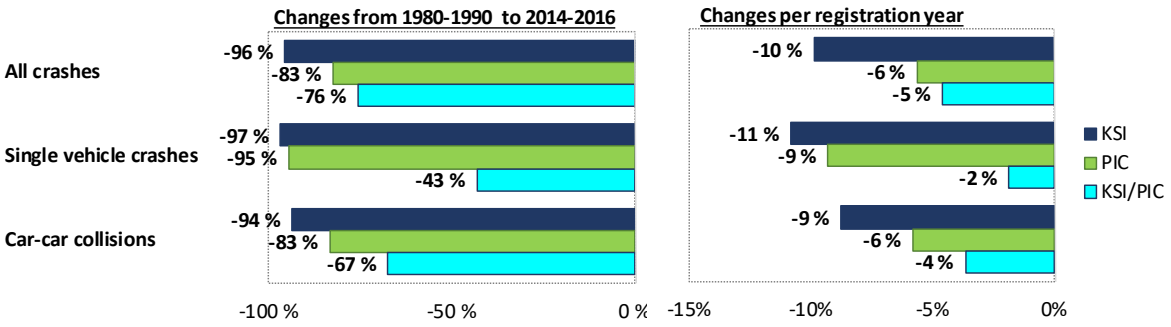

Figure S.1. Estimated effects of registration year on KSI, PIC (per vehicle km), and crash severity (KSI/PIC); changes from registration years 2014-2016 in comparison to registration years 1980-1990 (left), and per registration year (right); adjusted effects (with statistical control for the cars' weight, the drivers' age and gender, and crash year, as well as the crash partners registration year and weight for car-car collisions).

The results in figure S.1 show that cars from later registration years have fewer crashes (KSI and PIC) and less serious crashes (KSI/PIC). The effects on crash severity are larger in car-car collisions than in single vehicle crashes. The decreases of crash numbers have been larger for lighter cars than for heavier cars, while the decrease of crash severity has been about equally large independent of weight (not shown in figure S.1).

Factors that have contributed to the effects of registration year are improvements of active safety (such as anti-lock brakes, electronic stability control, and generally improved handling characteristics) and passive safety (such as side airbags and improved results in the crash test program Euro NCAP). The results from the present study are well in accordance with results from other studies.

However, the estimated effects of registration year may be somewhat overestimated. Despite statistical control for several potential confounding variables, the results are likely to be affected by the relationships between registration year and:

- Weight (later car models are on average heavier; heavier cars have on average less serious crashes)

- Age (later car models are in the present study on average newer; newer cars have on average fewer crashes)
- Crash year (lager car models have in the present study on average crashed in later years; crash risk and crash severity have on average declined over time, partly because of improved vehicle safety, and partly because of other factors).

If these effects are «removed» from the unadjusted effect of registration year in a hypothetical calculation, the number of KSI car drivers in cars from 2014-2016 is 72% lower than in cars from 1980-1990, or reduced by 4.2% per registration year.

Registration year and aggressivity: Fewer crashes with cars from later years and less serious injuries among pedestrians and cyclists

Aggressivity refers to the risk a car imposes to other road users (it has nothing to do with the drivers behavior). Cars from later registration years are less often crash partner in car-car collisions than cars from earlier registration years. The effect is about as large as the effect of registration year on own risk and it is due to the same factors that have contributed to the decrease of own risk for later model years. Crash severity (KSI/PIC among drivers of the own car) is not related to the crash partners registration year. This indicates that more recent cars not necessarily are less aggressive than cars from earlier years.

Cars from later registration years were found to have fewer crashes with pedestrians and cyclists and to inflict less serious injury on them. The numbers of crashes and injuries among pedestrians and cyclists have decreased by about 60-70% for cars from registration years 2014-2016 compared to registration years 1980-1990. Among the factors that have contributed to the decrease of injury severity are changes in the design of the cars' front.

Weight and own risk: Less serious crashes with heavier cars

On average in all types of crashes, an increase of vehicle weight by 100 kg reduces the number of KSI drivers by 4.9%. Vehicle weight has the largest effect in car-car collisions (-11.1% KSI per 100 kg weight increase). In single vehicle crashes no relationship was found between the number of KSI and weight. The number of PIC has not been found to be related to weight in any kind of crash. The results from the present study are in accordance with results from other studies, both with respect to the size of the overall effect and the difference between crash types.

Contributing factors to the effect of increasing weight on injuries are the (on average) larger size and thus larger deformation zones of heavier cars. Moreover, in collisions with other cars, speed changes and deformation are on average lower in heavier/larger cars than in lighter/smaller cars. However, in rollover crashes increasing weight may contribute to increasing impact force and deformation and thus more serious injuries. This may at least partly explain the lack of effect of vehicle weight in single vehicle crashes.

Weight and aggressivity: More serious collisions with heavier crash partners

Car-car collisions are on average more serious for car drivers when the crash partner is heavier. The number of KSI car drivers increases on average by 6.8% for each 100 kg increase of the crash partner's weight. Injury severity (KSI/PIC) increases on average by 10.3%. These results are in accordance with results from other studies. They show that the improved protection provided by increasing weight to the driver of the own car, comes at the cost of increased risk for crash partners. The effect of the crash partner's weight on own injury risk is larger in heavier cars than in lighter cars.

In collisions with pedestrians and cyclists, each increase of vehicle weight by 100 kg increases the risk for KSI among pedestrians/cyclists on average by 4.6%. This is most likely not an effect of weight per se, but due to a less «pedestrian friendly» design of heavier vehicles. The results also indicate that heavier cars impose higher crash risk to pedestrians and cyclists.

Age and own risk: More and more serious crashes with older cars

Older cars of up to 20 years of age have on average more and more serious crashes than newer cars, independent of registration year. The results from the present study show that, compared to a 20 year old car, the number of KSI drivers is reduced by 30% in 10 year old cars, by 42% in a five year old car, and by 50% in a new car (with statistical control for registration year and the drivers age and gender). Factors that contribute to the increasing risk of older cars are increasing technical defects and more high-risk behavior among drivers. Among other things, drivers of older cars are more often drunk and/or driving too fast, and they use more seldom seat belts than drivers of newer cars. Older cars also have more often young male drivers.

Among cars over 20 years, increasing age is related to fewer and less serious crashes, probably because of a «veteran car» effect, i.e. drivers of very old cars driving less and especially carefully.

Drivers age and gender: Young men have higher risk and impose greater risk to other road users than other drivers

Young drivers, especially young men, are more often KSI than other drivers, especially in single vehicle crashes. Older drivers are also more often KSI than drivers in the middle age groups, but less often than the youngest. While young men are more often KSI than young women, there are no large or statistically significant differences between men and women in the age groups above 25 years. Young men impose also considerably larger risk to pedestrians and cyclists than other drivers. The results from the present study are in accordance with results from other studies.

Increased renewal rate: Larger decrease of the number of KSI drivers (hypothetical calculation)

Hypothetically, if the whole current Norwegian passenger car fleet were replaced by new cars, the number of KSI car drivers would be reduced by 30%. By increasing the renewal rate of the passenger car fleet, the number of KSI car drivers may be halved (compared to 2015) in 2039 instead of in 2045.

These estimates are based on hypothetical calculations, based on the assumption that the number of KSI car drivers decreases by 4.2% for each new registration year. Other factors that affect crash and injury risk are not taken into account. For example, it is not taken into account that drivers of older cars on average show more high-risk behavior than drivers of newer cars and that they hardly will stop doing so if they were given a new car. The total annual mileage for the entire passenger car fleet is assumed to remain unchanged.