Positive Externalities from Active Car Safety Systems
A New Justification for Car Safety Regulations

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Abstract. This paper aims at broadening the theoretical justifications of traffic safety regulation. In a simple theoretical model we show that externalities occur when a driver's safety actions lower the probability that other drivers cause traffic accidents or a driver's safety actions lower the damages occurring in the case of other drivers causing accidents. Based on a large dataset of traffic accidents in Germany we show that the second sort of externalities is in fact empirically relevant for the case of anti-lock-brakes and electronic stability programmes. Thus, the demand for these active car safety systems would likely be suboptimally low in an unregulated market.

Keywords: Regulation, Driving Safety, Externalities, Transport

JEL code: K23, L62, L51

1. Introduction

The World Health Organization (2004) estimated that 1.2 million people were killed (2.2% of all deaths) and 50 million more were injured in motor vehicle collisions worldwide. Mortality rates, defined as road traffic fatalities divided by population differ considerably by age and sex. According to the World Report on Child Injury Prevention (World Health Organization (2008)) motor vehicle collisions are the leading cause of death among children worldwide 10 to 19 years old. Mortality rates differ also considerably by region. Low- and middle income countries tend to have higher road traffic fatality rates than their high-income counterparts. More than 90% of the world's fatalities on the roads occur in low-income and middle-income countries, although they have only 48% of the world's registered vehicles (World Health Organization (2009)).

The costs arising from accidents are enormous. The American Automobile Association (AAA) recently estimated the total annual cost from traffic accidents to be 164.2 billion US Dollar.[1] Similarly, the Federal Highway Research Institute (BASt) estimated the costs of accidents in Germany to account for roughly two percent of the German gross domestic product in 2004 (BASt (2006)). In the light of these numbers it is not surprising that especially governments of high-income countries have quite actively engaged in regulatory policies aiming to reduce the level of occurring accidents as well as of injuries sustained in crashes.

In most countries policymakers' view on the necessity and legitimacy of road safety regulation changed dramatically over time. We might illustrate this with the example of the United States.[2] Initially, automobiles were seen as a giant leap forward in the safety of transporting passengers. Due to the low driving speed of the early cars, serious accidents were rare. Although the death toll increased over the years with rising capabilities of cars driving at greater speeds, no serious attempts were undertaken to increase vehicle and traffic safety. This was primarily due to the positive image cars had at that time. Most Americans viewed automobiles as "means to increase the personal freedom and mobility

[1] See American Automobile Association (2008).
[2] See Lee (1998) for a review of the history of auto safety regulations in the United States.

of a highly mobile population" (Lee (1998), p. 392). The situation changed not before the 1960s when traffic fatalities escalated and Ralph Nader (1965) published his famous book "Unsafe at Any Speed". In this book he argues that many automobiles produced in the United States suffered from serious constructional flaws. While the book is openly polemical, it refers to the technical literature and also delivers material from industry insiders. In any case Nader's book contributed significantly to the unanimous passage of the 1966 National Traffic and Motor Vehicle Safety Act. The act established the National Highway Traffic Safety Administration and was the starting point towards a long series of regulations of automobile and driving safety in the United States. Although the plot differed from country to country, similar developments can be found in other OECD countries.

Nowadays, in most high-income countries a long list of regulations exists, which is concerned with road traffic safety. Roughly, these regulations can be subdivided into three groups: those focusing on car manufacturers, those which are concerned with the behavior of car drivers and passengers and those which deal with provision of road infrastructure. Examples for the first group are the obligation to supply cars with seat belts, crush-resistant windshields, padded instrument panels or energy-absorbing steering columns. The recent decision of the European Commission towards a mandatory equipment of all new cars with electronic stability programs also belongs to this group. The second group consists of regulations such as the obligation to make use of seat belts, adhere to speed limits or the ban on drunk driving. The third group covers regulations of the design and operational standards of roads (or, more broadly, road infrastructure).

The literature on vehicle safety regulation almost exclusively centers around the question which regulatory measures should be taken in order to decrease the risk and consequences of traffic accidents. Most of this literature refers to the seminal contribution of Peltzman (1975), arguing that drivers would respond to certain technical regulations by driving less safely (e.g. driving at faster speeds, more aggressive passing, less care, decreased attentiveness), because increasing technical safety standards make it less costly for them to do so. This behavior would at least partially offset the effects of engineering improvements and might lead to an increase in both accidents rates and severity of injuries.[3] Peltzman (1975) as well as numerous later studies[4] presented empirical evidence in favour of the described offsetting behavior.

Interestingly enough, neither the public nor the scientific debate about traffic safety is very much concerned with the theoretical foundations of traffic safety regulations. The necessity to regulate the market for vehicle and driving safety seems to be the most natural thing and not worth to be discussed in depth. This paper aims at contributing to filling this gap in the literature. We argue that most arguments employed to justify vehicle and driving safety regulations are unconvincing. We introduce a new argument into the discussion, which has yet not been discussed: positive externalities resulting from safety actions. We base our line of argument on a comparatively simple theoretical model and show under which circumstances these externalities occur. We then present empirical evidence in favor of the hypothesis that these externalities in fact exist and thus deliver a new pillar on which vehicle and driving safety regulations might be based.

The paper is structured as follows. Section 2 briefly reviews the literature on the justification of vehicle and driving safety regulations. In section 3 we present a theoretical model showing under which circumstances positive externalities of safety actions occur. Section 4 presents the dataset we use in our empirical analysis. In section 5 we discuss the estimation approach and present the empirical results. Section 6 concludes and discusses questions open to further research.

2. Justifications for traffic safety regulation

Most politicians' view on safety regulations is characterized by the opinion that the mere existence of risk is per se undesirable and should be eliminated at almost any cost.[5] This

[3] See also Viscusi (1984) and House (2006) for theoretical assessments of offsetting behavior in consequence of safety regulations.

[4] See e.g. Crandall et al. (1986), Chirinko and Harper (1993), Traynor (1993), Keeler (1994), Peterson, Hoffer, and Millner (1995), Dee (1998), McCarthy (1999), Calkins and Zlatoper (2001), Yun (2002), Cohen and Einav (2003), Harless and Hoffer (2003) and Winston, Maheshri and Mannering (2006).

[5] See Viscusi and Gayer (2002), p. 55.

view is substantiated when reading through official documents explaining why certain measures of traffic safety were taken. As an example, the European Commission writes in its Green Paper of 1995:

> "Transport accidents are a human tragedy, whether they occur in road, rail, inland waterways, aviation or, maritime transport. In the Community every year about 50,000 individuals are killed in transport accidents, almost all in road traffic accidents... [] ... Large regulatory efforts have been made, and should continue to be made, to reduce the risk of accidents in transport irrespectively of mode."[6]

Similar statements, almost always lamenting the high number of the injured and dead, can be found in official documents of almost any developed country.[7] Among most safety professionals, politicians and even international organizations such as the World Health Organization[8] there is the widespread belief that road traffic deaths and injuries are to a great extent preventable by driving carefully (e.g. at lower speeds) and making use of active and passive driving and vehicle safety systems. In the already cited European Commission's Green Paper we can read

> "New design methods can increase the protection of passengers and, through adequate design of the exterior of cars, reduce injuries to pedestrians. Moreover, further improvements may be expected through the introduction of active safety technologies, which should help prevent collisions from occurring in the first place."[9]

In consequence, governments around the globe focus their efforts on pressing engineers to develop various sorts of active and passive safety systems.[10] Moreover, the existing regulations force traffic participants to make use of these safety systems and to stick to certain driving safety standards. Behind this reasoning there is the implicit assumption that the associated increases in cost and the utility reductions from sticking to the rules

[6] European Commission (1995), p. 22.
[7] For the case of Germany compare e.g. Füll, Möhl and Rüth (1980), p. 451.
[8] See e.g. World Health Organization (2004), p. 109.
[9] European Commission (1995), p. 23.
[10] Passive systems aim at easing or even avoiding the consequences of occurring accidents. Among the most important of these systems are deformable zones, seat belts, airbags and e-call. Active safety systems aim at both lowering the probability of accidents occurring and alleviating the consequences of unavoidable accidents. The most important active safety systems are antilock brake systems (ABS), electronic stabilization programmes (ESP) and traction control systems (TCS).

are negligibly small.[11] Interestingly enough, the fact that a society without any risk would be tremendously costly and is thus infeasible is rarely a policy concern of consequence.

The economic approach to (safety) regulation is quite different. Most economists believe individuals to make rational choices between available alternatives of behavior, thereby comparing the costs and benefits of different courses of action. Individual plans are coordinated on markets. Under the conditions of perfect competition, markets always deliver Pareto efficient allocations. Thus, from an allocative perspective, there is no room for governmental intervention. However, when the conditions necessary to guarantee perfect competition are not met, the market might fail to allocate resources efficiently. Economists identified four generally accepted reasons for market failure: natural monopolies, public goods, informational asymmetries and externalities.

While natural monopolies and public goods play no role in the context of vehicle and driving safety, some authors argue that informational asymmetries might serve as a justification of regulation.[12] According to this view, the consumers of vehicle or driving safety are badly informed about either the risks of unsafe driving or the advantages of undertaking safety efforts. Both leads to a suboptimally low demand for safety actions and thus constitutes a market failure which calls for safety regulation. However, one might argue that providing the lacking information is superior to any technology-forcing regulation since traffic participants are not constrained in their individual choices.[13]

One might also argue that traffic accidents in general might cause spillover effects on the rest of society.[14] In welfare states public agencies or insurances play key roles in the protection and promotion of the economic and social well-being of the citizens. The welfare state is especially concerned with taking over responsibility for those unable to avail themselves of the minimal provisions for a good life. The fact that the state covers the costs of citizens falling short of the minimum requirements might cause serious moral hazard behavior of citizens and thus result in excessive costs. For example, traffic

[11] For a similar view see Lave (1987), p. 30.
[12] See e.g. Arcuri (1999).
[13] See e.g. Schwartz and Wilde (1979) and Viscusi and Gayer (2002), p. 60.
[14] See e.g. Seebode (1986).

participants might decrease their safety efforts since they expect to be supported by the state whenever they suffer a serious injury from a traffic accident causing excessive health care or recovery costs or leading to permanent total disability. Several states such as e.g. Germany follow this line of argument when justifying traffic safety regulations.[15] However, one might question whether this sort of moral hazard behavior in fact occurs in a magnitude sufficient to justify the enormously high level of traffic safety regulation in most developed countries.

Interestingly enough, positive externalities resulting from individual safety efforts have not played a significant role in the discussion, yet. In the following section we study under which circumstances these externalities might occur.

3. Model

3.1. Assumptions

We assume a model economy consisting of two risk-neutral individuals i, j with identical characteristics. Both individuals travel to work by car and earn an income of m. However, on their way to work they face the risk to get involved in an accident with the other driver. Each driver $i(j)$ is assumed to cause an accident with probability $p_i(p_j)$. When driving to work, individuals choose a level of safety actions $s_i(s_j)$. One might think of a broad set of these actions involving driving speed, use of safety belts, using a car equipped with airbags or active safety systems such as an electronic stabilization programme. We assume safety actions undertaken by a driver to decrease the probability of this driver causing an accident. However the probability of causing an accident might also depend on the level of safety actions the other driver chooses. Thus, at the example of driver i we can define

$$p_i = p_i(s_i, s_j) \tag{1}$$

with

$$\frac{\partial p_i}{\partial s_i} < 0 \tag{2}$$

[15] See Seebode (1986), p. 267.

and

$$\frac{\partial p_i}{\partial s_j} < 0. \tag{3}$$

Moreover we assume the marginal benefit from increasing the level of safety to decrease with increasing safety, i.e.

$$\frac{\partial p_i^2}{\partial^2 s_i} > 0 \tag{4}$$

and

$$\frac{\partial p_i^2}{\partial^2 s_j} > 0. \tag{5}$$

Whenever an accident occurs, the aggregate damage resulting from the accident has to be covered by the driver causing the accident. We assume the occurring damage to be a function of the safety levels chosen by both drivers involved in the accident. Let l_i be the aggregate damage occurring in consequence of an accident caused by i. We then have

$$l_i = l_i(s_i, s_j) \tag{6}$$

with

$$\frac{\partial l_i}{\partial s_i} < 0 \tag{7}$$

and

$$\frac{\partial l_i}{\partial s_j} < 0. \tag{8}$$

Again we assume the marginal benefit of safety actions to be decreasing with increasing safety, i.e.

$$\frac{\partial l_i^2}{\partial^2 s_i} > 0 \tag{9}$$

and

$$\frac{\partial l_i^2}{\partial^2 s_j} > 0. \tag{10}$$

However, safety actions are costly. For simplicity, we assume a constant cost per unit of safety c.

3.2. Individual optimization problem

Each individual is interested in maximizing net expected income $E[y]$ by choosing the appropriate level of safety actions. If not involved in an accident, i's net income is $m - s_i \cdot c$.

Alternatively, if involved in an accident, i's income is $m - l_i(s_i, s_j) - s_i \cdot c$. Thus, i's expected net income is given by

$$\begin{aligned} E[y_i] &= p_i(s_i, s_j) \cdot (m - l_i(s_i, s_j) - s_i \cdot c) + (1 - p_i(s_i, s_j)) \cdot (m - s_i \cdot c) \\ \Leftrightarrow E[y_i] &= m - p_i(s_i, s_j) \cdot l_i(s_i, s_j) - c \cdot s_i. \end{aligned} \tag{11}$$

The first-order-condition reads

$$-\frac{\partial p_i(s_i, s_j)}{\partial s_i} \cdot l_i(s_i, s_j) - p_i(s_i, s_j) \cdot \frac{\partial l_i(s_i, s_j)}{\partial s_i} = c \tag{12}$$

and demands to choose s_i as to equalize i's marginal benefits and marginal costs from undertaken safety actions.

Due to the assumption of identical individuals the first-order-condition for j is the same as for i. Thus, both drivers choose the same level of safety. We define the safety level solving equation 12 as $s_i^*(s_j^*)$. The equilibrium safety levels also allow to calculate the expected probability of each driver causing an accident and the expected damages resulting from the likely occurring accidents.

3.3. Collective optimization problem

In order to study, in how far the individually optimal safety levels are also optimal from the collective point of view, we now switch to the perspective of a welfare-maximizing social planner. The social planner chooses the safety levels s_i, s_j as to maximize expected aggregate income $E[y] = E[y_i] + E[y_j]$ with individual incomes given by equation 11. Thus, we have

$$E[y] = E[y_i, y_j] = 2 \cdot m - c \cdot (s_i + s_j) - p_i(s_i, s_j) \cdot l_i(s_i, s_j) - p_j(s_i, s_j) \cdot l_j(s_i, s_j). \tag{13}$$

In this case, the first-order-condition for i reads

$$\begin{aligned} &-\frac{\partial p_i(s_i, s_j)}{\partial s_i} \cdot l_i(s_i, s_j) - p_i(s_i, s_j) \cdot \frac{\partial l_i(s_i, s_j)}{\partial s_i} \\ &-\frac{\partial p_j(s_i, s_j)}{\partial s_i} \cdot l_j(s_i, s_j) - p_j(s_i, s_j) \cdot \frac{\partial l_j(s_i, s_j)}{\partial s_i} = c \end{aligned} \tag{14}$$

demanding to choose s_i as to equalize collective benefits from safety actions and marginal costs from undertaken safety actions.

Again, due to the assumption of identical individuals the first-order-condition for j is identical and thus the social planner will choose the same level of safety for both drivers. We define the safety level solving equation 12 as $s^*_{i,SP}(s^*_{j,SP})$.

3.4. Conclusion

The two first-order-conditions differ by two additional marginal benefits resulting from safety actions of an individual i. First, the social planner takes into account that the safety level chosen by individual i decreases the probability of j causing an accident, i.e.

$$-\frac{\partial p_j(s_i, s_j)}{\partial s_i} \cdot l_j(s_i, s_j). \tag{15}$$

This effect is not taken into account by individuals and thus constitutes a positive externality. We refer to this sort of externality as "risk externality" in the following.

Second, the social planner considers the effect of i's safety actions on damages caused by j, i.e.

$$-p_j(s_i, s_j) \cdot \frac{\partial l_j(s_i, s_j)}{\partial s_i}. \tag{16}$$

Again, this effect is neglected in the optimizing behavior of individuals. We refer to this type of externality as "damage externality" in the following.

It is easy to see that in consequence of the described risk and damage externalities the individually optimal safety levels are below the socially optimal levels. Thus, we have

$$s^*_i = s^*_j < s^*_{i,D} = s^*_{j,D}. \tag{17}$$

In the model, these externalities result from the assumptions we made on the effects of individual safety actions. In how far these externalities occur in reality is an empirical question. In the following we therefore turn to an empirical analysis of the existence of the described externalities.

4. Data

4.1. Data sources

Most of the data we employ for the empirical analysis come directly from the GIDAS-database (German In-Depth Accident Study), the largest accident study in Germany. The project is supported by the Federal Highway Research Institute (BASt) and the German Association for Research in Automobile Technology (FAT). The data collected in the GIDAS project is very extensive (roughly 3.000 data per accident) and serves as a basis of knowledge for different groups of interest. Due to a well defined sampling plan, representativity compared to the federal statistic is guaranteed. Since mid 1999, the GIDAS project collects data on about 2.000 accidents in the areas of Hanover and Dresden (see figure 4.1) per year. However, the database consists only of data on accidents with personal injuries.

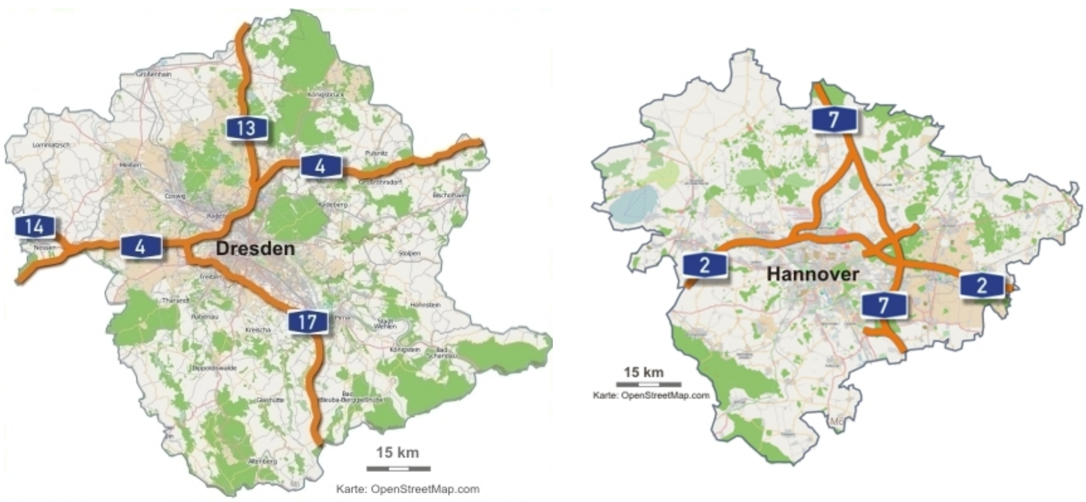

Figure 1. Sample areas of the GIDAS-database

Our sample covers the period of July 1999 until June 2008. In order to study in how far active car safety systems in fact cause external effects we focus on accidents with at least two vehicles. Moreover we exclude all accidents with more than two cars from the sample since causation issues are often quite complex in accidents with multiple vehicles.

For each accident we have four different sorts of data. First, information on the circumstances under which the accident took place are available. Second, we have data on the causes of the accident. Third, we have data on who caused the accident. And finally, the dataset covers various information on the car which was responsible for causing the accident. The same data is also available for the second involved car.

Table I. Variables

Variable	Type of variable
In town	Dummy (0 = no, 1 = yes)
Rain	Dummy (0 = no, 1 = yes)
Hail	Dummy (0 = no, 1 = yes)
Snow	Dummy (0 = no, 1 = yes)
Constant wind	Dummy (0 = no, 1 = yes)
Squally wind	Dummy (0 = no, 1 = yes)
Fog	Dummy (0 = no, 1 = yes)
Wet street	Dummy (0 = no, 1 = yes)
Lubricous street	Dummy (0 = no, 1 = yes)
Slippery street	Dummy (0 = no, 1 = yes)
Night	Dummy (0 = no, 1 = yes)
Twilight	Dummy (0 = no, 1 = yes)
No roadworthiness	Dummy (0 = no, 1 = yes)
Driving mistake	Dummy (0 = no, 1 = yes)
Driving at excessive speed	Dummy (0 = no, 1 = yes)
Inappropriate distance	Dummy (0 = no, 1 = yes)
Overtaking	Dummy (0 = no, 1 = yes)
Violation of right of way	Dummy (0 = no, 1 = yes)
Turn off	Dummy (0 = no, 1 = yes)
Loading	Dummy (0 = no, 1 = yes)
Passengers involved	Dummy (0 = no, 1 = yes)
Engineering deficiency	Dummy (0 = no, 1 = yes)
Passing	Dummy (0 = no, 1 = yes)
etc. (altogether: 19)	Dummy (0 = no, 1 = yes)
Age of driver	metric
Gender of driver	Dummy (0 = male, 1 = female)
Years of driving experience	metric
Alcohol	Dummy (0 = no, 1 = yes)
Vehicle age	metric
Engine power	metric
kilometer reading	metric
Vehicle weight	metric
Antilock brake system (ABS)	Dummy (0 = no, 1 = yes)
Electronic Stabilization Programme (ESP)	Dummy (0 = no, 1 = yes)
Traction Control System (TCS)	Dummy (0 = no, 1 = yes)
Number of occupants	metric
Injury of occupants	MAIS-score

While the database contains no information on material damages, there is information on the injuries of the occupants in both involved cars. For every single occupant the so-called MAIS-score is available. The Abbreviated Injury Scale (AIS) is a well established anatomical scoring system to assess trauma severity (see Baker et al. (1974) and Copes et al. (1988)). It was first introduced in 1969 and has been revised and updated various times. The latest version of the AIS score is the 1998 revision. The AIS is monitored by a scaling committee of the Association for the Advancement of Automotive Medicine. As depicted in table II injuries are ranked on a scale of 1 to 6, with 1 being minor, 5 severe, and 6 a nonsurvivable injury. This represents the 'threat to life' associated with an injury and is not meant to represent a comprehensive measure of severity. The AIS-score is available for 6 different body regions.[16] The MAIS-score is defined as the maximum AIS-score for all body regions.

Table II. MAIS-Scores and Monetarization

MAIS-Value	Severity of Injury	Monetized Damage (Euro)
0	none	0
1	minor	11.429
2	moderate	16.828
3	serious	53.915
4	severe	212.464
5	critical	452.293
6	unsurvivable	1.376.306

In order to be able to compare the external effects from car safety systems with their costs we decided to monetize the MAIS-scores. We thereby followed the same procedure as employed by the Federal Highway Research Institute (BASt) to estimate the monetized valuation of prevention of traffic accidents.[17] As a result of the monetization procedure we end up with the numbers displayed in the last column of table II.

4.2. Descriptive statistics

Altogether, the final dataset consists of data on a total number of 2.435 accidents in which 4.870 cars and 7.590 persons were involved. 68% of the accidents were caused by male drivers while the drivers of the car not causing the accident were male in only 64% of all accidents. The distribution of injuries among the occupants in the two cars is shown in table III. The numbers indicate clearly that the occupants of the car not causing the accidents on average suffer more severe injuries than the occupants of the

[16] These body regions include: (1) head or neck, (2) face, (3) chest, (4) abdomen or pelvis contents, (5) extremities or pelvic girdle and (6) external (such as skin).
[17] For a documentation of the monetization procedure see BASt (1999,2006).

accident-causing car. While 58% of the occupants of the car causing the accident suffer no injury (MAIS score 0) this holds true for 37% of the occupants of the other involved vehicle.

Table III. Distribution of MAIS scores among involved car occupants

	MAIS 0	MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	MAIS 6	MAIS unknown	sum
Causing car	2113	1131	225	42	23	5	5	84	3628
Percentage	58,24	31,17	6,20	1,16	0,63	0,14	0,14	2,32	100,00
Not causing car	1450	2144	216	36	8	5	3	100	3962
Percentage	36,60	54,11	5,45	0,91	0,20	0,13	0,08	2,52	100,00
Both cars	3563	3275	441	78	31	10	8	184	7590
Percentage	46,94	43,15	5,81	1,03	0,41	0,13	0,11	2,42	100,00

72 % of the accidents took place in town while the remaining 28% happened out of town. On average, the cars involved in accidents were 7.5 years old. The involved drivers had, on average, 15 years of driving experience. In only 2,1 % of all cases, the driver responsible for the accident consumed alcohol.

While there is a considerable number of different active driving safety systems, only a few of them are turning up in the sample sufficiently often to be included in the empirical analysis. Among them are antilock brake systems (ABS), electronic stabilization programmes (ESP) and traction control systems (TCS). Roughly half of all cars in the dataset (46%) were equipped with antilock brake systems. Cars with traction control systems (13%) and electronic stabilization programmes (12%) turn up in the dataset less often. However, the frequencies do not differ between the cars causing and not causing accidents.

5. Estimation approach and empirical results

Since our database consists only of data on factually occurred accidents, we are not able to study the existence of positive risk externalities. However, the data allows to study in how far damage externalities occurred. As a consequence of the fact that we have no information on the physical damages of the vehicles in the database we concentrate on monetized injuries of the occupants of the involved cars. Moreover, we concentrate on damage externalities caused by active car safety systems such as antilock brake systems (ABS), electronic stabilization programmes (ESP) and traction control systems (TCS).

Our estimation strategy consists of pooling all data and running cross-section regressions with monetized injuries as endogenous variable. In a first step we study in how far the active safety systems of the car which has not caused the accident contributed to lowering the monetized injuries in the same car. We therefore estimate the following regression

$$MD_i^{NL} = \alpha + \beta \cdot CV_i + \gamma_1 \cdot ABS_i^{NL} + \gamma_2 \cdot ESP_i^{NL} + \gamma_3 \cdot TCS_i^{NL} + \epsilon_i \qquad (18)$$

with MD^{NL} (the index 'NL' means 'not liable', while 'L' stands for 'liable') being the average monetized injury of the occupants in the car not causing the accident, CV being a vector of control variables, ABS, ESP and TCS being dummy variables for the car being equipped with an antilock brake system (ABS), electronic stabilization programme (ESP) and traction control system (TCS). The variable α is the regression constant, β the vector of coefficients of the utilized control variables and ϵ the unexplained residual of the regression. The coefficients γ of the dummy variables representing the equipment with active car safety systems are in the focus of our interest. If the active safety systems in fact cause positive damage externalities (i.e. reductions in damage) the referring γ-coefficients should be significantly negative.

The regression results are summarized in table IV. Besides the regression constant, only four control variables turn out to be significant.[18] First, injuries are significantly lower if the accident happened in town. Second, injuries are significantly higher if the accident was caused by driving at excessive speed. Third, more severe accidents occur during daytimes. Fourth, drivers tend to drive more carefully with increasing number

[18] At first glance one might wonder why most control variables turn out to be insignificant. For example, one might suspect that more accidents happen under slippery road conditions. However, our database consists only of factually occurred accidents. Thus, the regression results indicate that, given that an accident occurred and given that occupants were injured, slippery road conditions have no significant influence on monetized injuries.

Table IV. Estimation results regression I

Variable	Coefficient	Standard Error	t-value	p-Value
Constant	17642.74	2666.098	6.617438	0.0000
In town	-8182.870	2437.509	-3.357062	0.0008
$Cause_{speed}$	12317.94	6496.590	1.896062	0.0581
Daytime	2338.419	1307.958	1.787839	0.0739
$Occupants_{NL}$	-2259.299	862.9841	-2.618008	0.0089
ESP^L	3037.753	3785.488	0.802473	0.4224
TCS^L	2117.346	2190.458	0.966623	0.3338
ABS^L	2163.062	1516.517	1.426335	0.1539
ABS^{NL}	-4180.771	1969.483	-2.122776	0.0339
ESP^{NL}	-2289.748	1144.534	-2.000593	0.0455
TCS^{NL}	490.2258	1048.040	0.467755	0.6400

We report White-corrected standard errors
$N = 2396$, $Adj.R^2$: 0.024, F-Value: 5.79^{***})

of occupants.[19] The active safety systems of the vehicle causing the accident turn out to have no significant effect on average monetized injuries in the car not causing the accident.[20]

However, in the focus of our study are car safety systems. In fact, we find evidence in favor of positive damage externalities. Both the coefficients of the dummy for the antilock brake systems (ABS) and electronic stabilization programmes (ESP) turn out to be significanlty negative. Whenever cars equipped with an antilock brake systems are involved in accidents they did not cause, the system lowers the average damage from injuries in the same vehicle by roughly 4.200 Euro. Similarly, the electronic stability programme lowers average injuries by almost 2.300 Euro. The coefficient of traction control systems is not significantly different from zero. Thus, we find no empirical evidence in favor of the hypothesis that traction control systems generate positive damage externalities.

Positive damage externalities would also occur if the safety systems built in the vehicle which did not cause the accident lower the monetized injuries of the occupants of the

[19] We also included various interaction terms into the regressions, but none of them turned out to be significant.

[20] It should be underlined that this result should not be misinterpreted as indication of disfunctionality of these systems. First, these systems might contribute to avoiding accidents or at least accidents with injured occupants. Second, they might contribute to lowering the injuries of the occupants in the car equipped with the system.

accident-causing car. In this case the safety systems of the vehicle not causing the accident contribute to lowering the costs which have to be covered by the liable driver. In order to study this aspect we estimate the following regression

$$MD_i^L = \alpha + \beta \cdot CV_i + \gamma_1 \cdot ABS_i^{NL} + \gamma_2 \cdot ESP_i^{NL} + \gamma_3 \cdot TCS_i^{NL} + \epsilon_i \tag{19}$$

with MD^L being the monetized injury of the occupants in the car causing the accident.

Table V. Estimation results regression II

Variable	Coefficient	Standard Error	t-value	p-Value
Constant	15802.92	2779.590	5.685341	0.0000
In town	-6548.539	2855.864	-2.293015	0.0219
$Cause_{speed}$	17807.47	7634.301	2.332561	0.0198
ESP^L	27.96101	1008.788	0.027717	0.9779
TCS^L	-2242.816	842.1218	-2.663292	0.0078
ABS^L	-6041.535	2074.481	-2.912312	0.0036
ESP^{NL}	-673.9206	1748.766	-0.385369	0.7000
TCS^{NL}	-128.1135	1570.098	-0.081596	0.9350
ABS^{NL}	-54.40320	2981.374	-0.018248	0.9854

We report White-corrected standard errors
$N = 2389$, $Adj.R^2$: 0.019, F-Value: 5.62^{***}

The regression results are summarized in table V. As in the first regression, the control variables for driving speed turn out to be significant. However, the safety systems in the accident-causing vehicle also have a significant effect on monetized injuries in the same car. Both, antilock brake systems and traction control systems contribute to a significantly lower average monetized occupant damage. However, positive damage externalities would require the safety systems of the car not causing the accident to lower injury damages in the accident-causing vehicle. Since the referring coefficients are not significantly different from zero, we find no supporting evidence for positive damage externalities in this case.

6. Summary and conclusions

While the market for traffic safety belongs to the most intensively regulated markets of high-income economies, there has been little discussion on the justification of these regulations. When introducing new regulations of traffic safety governments almost always argue that the risk of traffic accidents occurring should be minimized without considering the costs resulting from the regulations. In this paper we contribute to the literature by arguing that safety actions might cause positive externalities on other market participants. Based on a simple theoretical model we show that externalities occur when a driver's safety actions lower the probability that other drivers cause traffic accidents. Externalities also occur when a driver's safety actions lower the damages occurring in the case of other drivers causing accidents. Based on a large dataset of traffic accidents in Germany we were able to show that the second sort of externalities is in fact empirically relevant for the case of antilock brakes and electronic stability programmes. Thus, the demand for these active car safety systems would likely be suboptimally low in an unregulated market. Thus, at least the necessary condition for regulation is fulfilled for these safety systems.

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