The cost of AI-driven accidents.
A law and economics analysis of liability rules in the age of self-driving cars

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Abstract

Despite the exponential growth in the development of automated driving systems in the past ten years, currently deployed automated vehicles (AVs) are far from being fully autonomous. As a matter of fact, human intervention is still necessary in most circumstances to take final decisions or to avoid system failures. International standardization bodies classify AVs according to their degree of autonomy, with Level 2 and 3 vehicles being semi-autonomous, namely requiring a safety driver to relinquish control if needed. When an accident occurs, the degree of interaction between human beings and machines and the control that the safety driver can exert on the AV bring about significant consequences for the attribution of liability. While fully autonomous AVs (Level 5) will most likely be subject to a strict liability regime, it is not clear yet which liability rule would be more suitable for semi-autonomous AVs (Level 2 and 3), which may induce over-reliance on the technology, resulting in an increased level of negligence by the operator. Evidence from other sectors (e.g. aviation) that have already witnessed a shift to full automation suggest that human operators might become the "moral crumple zone" (Elish, 2019) of accidents involving automated vehicles, being consistently blamed for negligence even in cases where their control on the machine is limited.

Against this backdrop, this paper evaluates whether the existing tort system is well equipped to tackle the new challenges brought about by semi-autonomous AVs, or whether novel rules should be designed to ensure adequate levels of safety without stifling innovation. This paper applies the law and economics analytical framework, and in particular the economic theory of torts, to semi-autonomous AVs. The contribution first surveys existing liability frameworks applicable to semi-autonomous AVs and then reflects on the hypothesis of attributing legal personality to AI systems. It argues that AVs will be likely to require more compliance efforts from both the manufacturer and the end-user in a semi-autonomy scenario, that is to say Level 2 and 3 AVs are compliance-using technologies. As a consequence, it argues that the role if the "human in the loop" should not be disregarded when analyzing the investment in precautions by potential tortfeasors and victims. Furthermore, it contends that the type of liability regime (from strict liability to negligence) is shaped by how lawmakers conceive the AVs in the first place. In this respect, it is debatable whether the legal personality hypothesis would be effective in a tort setting. While this legal fiction works for corporations, in case of AVs it would not relieve the manufacturer or the owner from the potential disbursements for damages and insurance, representing an additional layer of complexity without solving the liability dilemma. Regulators should envisage technology specific mechanisms for AI-driven accidents where human negligence persists, which would incentivize the adoption of adequate levels of precautions without discouraging firms' investments in innovation. An integrated approach involving both ex ante regulation and ex post tort law could help achieve an efficient system which would allow to tackle the challenges brought by AVs.

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1.1 Introduction

This paper discusses the choice of a liability regime in case of wrongs involving artificial intelligence (AI) systems, addressing the traditional law and economics dilemma between safety and innovation while exploring possible options to attribute responsibility to parties.

The starting assumption of this paper is that current AI applications are far from being fully autonomous. As a matter of fact, they are able to perform at most one main task, and human intervention is still necessary to avoid systems failures or take final decisions. The degree of interaction between human beings and machines brings about significant consequences for the attribution of liability when an accident occurs. For instance, partially automated vehicles[1] (where a safety driver[2] is required to relinquish control if needed), may induce over-reliance on the technology, resulting in an increased level of negligence by the operator. Existing contributions from the economic analysis of law have tackled the problem of liability for automated technologies as well as other risky activities characterized by a certain degree of uncertainty. However, the extant literature has not dealt with care investments when humans are "in the loop" of an AI system, namely when human operators play a significant role. Evidence from other sectors that have already witnessed a shift to *quasi* full autonomy suggests that human operators might become the *"moral crumple zone"* of accidents involving AI systems, being consistently blamed for negligence in cases where their control is limited.

In this context, it is worth asking how liability should be attributed when a given technology is automated but not autonomous and how adequate levels of safety and innovation can be ensured. The paper first surveys possible liability frameworks applicable to AI systems and then reflects on the largely discussed hypothesis of attributing legal personality to algorithmic agents. It argues that the human in the loop should be considered when analyzing the level of care and activity. Furthermore, it contends that the type of liability regime and the consequent choice of remedy is shaped by how lawmakers conceive AI in the first place. In this respect, building a liability regime that deems AI as a fully autonomous entity sounds unrealistic at the current stage of knowledge, as full autonomous machines are far from being put on the market in the short term. Therefore, regulators should not fall in the trap of creating a "law of the unicorn" in an attempt to anticipate risks stemming from fully autonomous agents that do not exist yet. This would disincentivize innovation and firms' investments in new technologies. On the contrary, mechanisms should be envisaged for technologies where human negligence persists. In this perspective, liability rules should accommodate the degree of automation of the technology.

The first part of the paper focuses on two features of AI systems, autonomy and interaction, and classifies automated vehicles according to their level of autonomy, assessing their costs and benefits. Then, the paper continues by presenting how tort law deals with technology and what automation implies in terms of liability risk. Section 1.3.3 discusses precautions, compliance-saving technologies and the role of negligence, while the following Sections present various liability regimes when autonomous vehicles are involved. Section 1.3.5 provides an overview of the debate on legal personality of AI. Section 1.4 concludes.

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[1] In this context, terms such as automated vehicle, driverless car, self-driving vehicle, autonomous vehicle and connected car are used interchangeably.

[2] Safety drivers are backup operators sitting in the driving seat of an automated vehicle, who are typically instructed to take the hands near the steering wheel in order to take back control of the automated driving system in case of emergency. In this paper, terms such as safety driver, backup driver and operator will be used interchangeably.

1.2 The state of AI applications and the myth of a driverless revolution

1.2.1 Interaction and autonomy in automated technologies

Contemporary applied research in artificial intelligence and robotics revolves around *interaction*, which envisages the simultaneous and symbiotic presence of humans and machines in disparate contexts, and *autonomy*, which refers to the ability of systems to act on the environment without the strict supervision of humans. In fact, the ultimate goal of cutting-edge AI applications is on the one hand to improve human performance thanks to their interplay with machines, and on the other to achieve full autonomy of agents, which is based on the ability to effectively delegate and control machines. These two concepts are profoundly intertwined and entail substantial repercussions from an innovation point of view.

In relation to *interaction*, experts are currently testing new man-machine interfaces cooperating in virtual environments, with the intention of applying them in social and industrial contexts where devices can intuitively and safely liaise with humans. The interactive behavior in machines (being they hardware, software of both) can be exploited in a broad range of sectors, including telemedicine, logistics and maintenance. For instance, collaborative robots such as power extenders, which provide the power of a robot to the body of a human, are being employed in disaster recovery. Extenders are beneficial for workers' health insofar they avoid muscular stress while also allowing for time savings. Nevertheless, such interactive systems entail some risks as well, which may well derive from electrical failures or unwanted motions.

When it comes to the deployment of *autonomous* systems, it should be emphasized that in the vast majority of cases, the term autonomy refers to at most a single task such as driving, exploring or assembling, therefore any apocalyptic advent of sophisticated self-sufficient humanoids seizing control of the world is nowhere near imminent. Autonomous technologies can replace humans in a wide range of potentially risky situations, from driving on highways to inspecting critical environments such as nuclear sites. Further applications can be found in storage management and logistics, as in the case of Amazon's warehouses, where robots are programmed to do tasks such as sorting or cleaning.

Both features coexist in automated driving systems (ADS) installed in connected and automated vehicles. The degree of interaction between the human operator and the technology as well as the level of autonomy displayed by the system are both relevant factors in case of wrongdoings, as they shape the way liability may be allocated. However, before delving into the rationale of liability rules, it is worth laying out in the next section the main features of autonomous vehicles, which represent the exemplary case of complex AI systems.

1.2.2 Autonomous vehicles: main features, expected costs and benefits

Autonomous machines are the most notorious example of automated driving technologies, such as self-driving cars, aircrafts and high-speed trains. While the shift to automation of high-speed trains and aircrafts well precede the third boom of AI history,[3] it is with the growing popularity

[3] Typically, experts distinguish three eras of AI. The first boom in AI history goes from 1956, year of the Dart.mouth summer research project on artificial intelligence, to 1974, where the general interest in the topic declined resulting in the so-called first 'AI winter'. In the period 1980-1987 a renewed interest in AI manifested among academics, who focused on knowledge-based approaches. However, it is only after the second 'AI winter' (1987-1993) that the new era of AI research flourished (third boom), thanks to the promising rise of neural networks and deep learning. For an in-depth historical perspective on AI see Catalina Goanta, Gijs van Dijck and Gerasimos Spanakis, 'Back to the Future: Waves of Legal Scholarship on Artificial Intelligence' [2019] Forthcoming in Sofia Ranchordás and Yaniv Roznai, Time, Law and Change (Oxford, Hart Publishing, 2019).

of machine learning that autonomous vehicles gained momentum in recent years, especially when tech-companies such as Google's Waymo launched their prototypes on the market.[4] However, after the hype of an imminent self-driving revolution, the Covid-19 pandemic, coupled with raising concerns regarding vehicles' safety and social acceptance, lowered the expectations and slowed down their uptake, to the point that now it seems that tech players have parked their bold ambitions.[5] In other words, the driverless society will come, but not soon as expected. Against this backdrop, this section outlines the features of autonomous vehicles as classified by standardization bodies such as the International Society of Automotive Engineers (SAE), and then discusses expected costs and benefits of their deployment.

SAE classifies vehicles into six levels according to their degree of autonomy.[6] The organization distinguishes vehicles where the human operator is in charge of all aspects of driving (Level 0) from vehicles characterized by full automation (Level 5), where the AI system takes over all the driving tasks without the need for human intervention. In between these two opposite poles we find partially automated cars, namely Level 1 vehicles, where the driving system can either accelerate/decelerate or steer (*e.g.* cars with the cruise control), and Level 2 and 3, where the system can take full control of the drive but the driver is ready to resume control. Currently, Level 2 and 3 vehicles are being tested and put on the market, while for instance in the UK companies are testing Level 4 prototypes.[7] The effective testing and deployment of autonomous cars depends on a plethora of factors, including the place (driving in Naples might be a completely different experience from driving in Los Angeles) as well as the part of urban landscapes (highways differ from city centers) where they will be used. It follows that new autonomous vehicles will be likely to be adopted and tested first in more controlled contexts before (if ever) being fully deployed. A further scenario may involve a mixed population of partially and fully automated vehicles, whereby a fully autonomous L5 truck will travel on long distance drives in ad hoc highways, while L2 or L3 cars will drive around city centers.

Automated vehicles entail several benefits. First, by replacing human drivers, they should ensure an enhanced level of safety, as 90% of current road accidents are due to human error.[8] Hence, through the deployment of automated vehicles, it is estimated that the number of accidents would decrease. The expected drop in road accidents would lead to less social and individual costs in terms of personal injuries and damages. In turn, this could also generate a reduction in insurance premiums.[9] At the same time, it is predicted that a shift towards full driving automation would reduce traffic congestion, thus improving urban mobility. As a

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[4] Andrew J Hawkins, 'Waymo Is First to Put Fully Self-Driving Cars on US Roads without a Safety Driver' (*The Verge*, 7 November 2017) <https://www.theverge.com/2017/11/7/16615290/waymo-self-driving-safety-driver-chandler-autonomous>.

[5] '"Peak Hype": Why the Driverless Car Revolution Has Stalled' (*the Guardian*, 3 January 2021) <∑>; Mark Anderson, 'The Road Ahead for Self-Driving Cars: The AV Industry Has Had to Reset Expectations, as It Shifts Its Focus to Level 4 Autonomy-[News]' (2020) 57 IEEE Spectrum 8.

[6] SAE International, 'Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles' <https://www.sae.org/standards/content/j3016_202104/> accessed 19 May 2021.

[7] '"Self-Driving" Cars to Be Allowed on UK Roads This Year' *BBC News* (28 April 2021) <https://www.bbc.com/news/technology-56906145> accessed 19 May 2021.

[8] Erica Palmerini and others, 'Guidelines on Regulating Robotics'; European Commission, 'Intelligent Transport Systems' (*Mobility and Transport - European Commission*, 22 September 2016) <https://ec.europa.eu/transport/themes/its/road_it> accessed 19 May 2021.

[9] James M Anderson and others, *Autonomous Vehicle Technology: A Guide for Policymakers* (Rand Corporation 2014).

consequence of less jammed roads, individuals could spend the saved time in other activities. In other words, enhanced urban mobility would bring along as a side effect a reduction in the opportunity cost of time spent driving.[10] A further positive implication of a full deployment of driverless cars lies in a future reconfiguration of vehicles design which will result in cost savings for the manufacturer. Once a lower level of collisions is achieved, one may think of removing certain safety items that are costly and will be no longer needed. Finally, driverless cars could lower the barriers for passengers with disabilities as well as elderly people, promoting personal independence and lessening social isolation.[11]

The sophistication of these systems involves complexities as well. Modeling human understanding and interaction is a hard job for developers. Autonomous driving systems lack a typical human feature, common sense, which allows individuals to perceive and handle exceptions. Such complexities lead to potential faults, resulting in machines acting in a way that is unexpected, which in turn might cause accidents. The "unpredictability element" is often due to logic faults in the code. These errors are difficult to detect, as they emerge only in particular testing conditions. Currently, researchers are working to take into account all the potential circumstances where a fault might occur but designing a test that would incorporate all the circumstances is an almost impossible challenge. Another drawback of the deployment of connected cars concerns privacy and cybersecurity vulnerabilities. Their heavy reliance on data makes them exposed to hacking and unwanted access by third parties, who might not only steal personal data, but also interfere with the system functioning.

In sum, in the long run a full transition to autonomous vehicles is likely to lead to less accidents and associated social costs. However, drawbacks and potential challenges persist, from privacy to legal uncertainty when driverless cars are implicated into traffic accidents. The next section delves into some of the complexities of accidents involving autonomous vehicles and the resulting challenges in allocating liability.

1.2.3 The complex ecosystem of AI-driven accidents

In May 2018, an automated test vehicle from Uber Technologies was operating on a self-driving mode on the streets of Tempe, Arizona, when it hit and killed a pedestrian who was walking a bike across the road. The vehicle was occupied by a safety driver, who was responsible for taking control when necessary and did not react in time to prevent the collision, allegedly because she was distracted by her phone. An ex post evaluation from the National Safety Transportation Board found that several factors had contributed to the crash.[12] First, the operator was watching a show on her smartphone, and did not notice the victim until 0.5 seconds before the collision. Second, although the onboard identification system was able to identify the victim six seconds before the impact, it wrongly classified her first as an unknown object, then as a car and finally as a bike. Apparently, the image recognition algorithm had not been programmed to identify human figures outside crosswalks. Third, Uber had deactivated the automatic emergency braking systems in the vehicle and disallowed the use of immediate

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[10] ibid.

[11] Henry Claypool, Amitai Bin-Nun and Jeffery Gerlach, 'Self-Driving Cars: The Impact on People with Disabilities' [2017] Ruderman Family Foundation: Newton, MA, USA; Heather Bradshaw-Martin and Catherine Easton, 'Autonomous or "Driverless" Cars and Disability: A Legal and Ethical Analysis.' (2014) 20 European Journal of Current Legal Issues.

[12] 'Collision Between Vehicle Controlled by Developmental Automated Driving System and Pedestrian' (National Transportation Safety Board 2019) Highway Accident Report NTSB/HAR-19/03.

emergency braking, relying instead on the safety driver.[13] In September 2020, the backup driver was charged with negligent homicide.[14]

The example above shows how complex is the assessment of factors causing an accident when an AI system is involved. Automated vehicles operate in a multifaceted ecosystem where data, hardware and software coexist with humans, being they the developer of the AI, the backup driver or just random people on the street. Also, it confirms that, when an automated vehicle relies upon a human to intervene and prevent an accident, humans are not the ideal type of backup in such situations, as they are "inattentive, easily distracted, and slow to respond".[15] In such composite context, the harm may arise from different sources. It may be due to i) a programming error; ii) a human error; iii) an autonomous error by the algorithm that takes an unexpected decision; or iv) an external factor such as a cybersecurity hack. These "novel" faults add up to more traditional ones, such as objects appearing in the middle of the street or a failure in the engine of the vehicle.

Besides the source of harm, when assessing liability, one must consider all the borderline scenarios where: i) an automated technology causes harm, but the contribution of the AI to the overall damage cannot be proven; ii) an AI system did not face any failure, but its interaction with a human operator caused harm; iii) an interaction between two or more algorithms led to damages to third parties; iv) the combination of two or more AI systems from different vendors in a single system caused harm without a way to distribute responsibility between the parties. In such a multidimensional context, where establishing the source of harm, the causality link and the fault proves to be a difficult task, the law and economics approach to tort may serve as a framework for the assessment of the liability regime where parties' incentives are aligned and the total cost of accidents is minimized.

1.3 An economic analysis of liability rules for AI-driven accidents

1.3.1 Tort law and technology: governing uncertainty

From a traditional legal standpoint, the main goal of the tort system is to protect – or at least compensate – victims from potential unjust injuries.[16] Such approach, based on the principle of corrective justice, diverges from the economic approach of *efficient deterrence* sponsored by law and economics scholars. In fact, from an economic analysis of accident law viewpoint, the tort system assigns liability to deter potential injurers from implementing tortious behavior while incentivizing the adoption of optimal precautions. Hence, from an economic efficiency perspective, the goal of any liability system is not *ex post* compensation but *ex ante* prevention.[17] In other words, the economic rationale behind tort law is the minimization of the total costs of accidents, as argued by Calabresi.[18] By adjusting potential injurers' incentives to take precautions, the tort system induces them to internalize the costs of their activity, that is to say it discourages individuals from engaging in an activity that might cause a negative

[13] ibid.

[14] 'Safety Driver in Fatal Arizona Uber Self-Driving Car Crash Charged with Homicide | Reuters' <https://www.reuters.com/article/uber-selfdriving-idUSKBN26708P> .

[15] Alex Davies, 'The Very Human Problem Blocking the Path to Self-Driving Cars' *Wired* <https://www.wired.com/2017/01/human-problem-blocking-path-self-driving-cars/> accessed 19 April 2021.

[16] Louis Visscher, *Debated Damages* (2014).

[17] Michael Faure, 'Attribution of Liability: An Economic Analysis of Various Cases' (2016) 91 Chi.-Kent L. Rev. 603.

[18] Guido Calabresi, *The Cost of Accidents: A Legal and Economic Analysis* (Yale University Press 1970).

externality. Liability rules such as negligence or strict liability can persuade potential tortfeasors to adopt precautionary actions. However, self-driving vehicles challenge the traditional scheme of incentives, as the driver can exercise limited or no control over the automated driving system, and, as showed above, an extra layer of complexity is given by the many sources of harm and the several factors contributing to an accident. Along with reducing negative externalities, tort liability promotes and protects positive externalities, namely diffuse benefits for society at large.[19] Undoubtedly, as illustrated above, innovations in products and services brought by AI generate significant societal advantages. Therefore, the tort system should also encourage a level of activity that would not disincentivize positive externalities. This tension between negative and positive externalities and the role of tort law brings about significant consequences when technologies like AI are involved. The next section delves into the main repercussions of such trade-off by looking at the switch of liability risks from the individual to the product.

1.3.2 Shifting the liability risk from the driver to the vehicle

The application of tort law to autonomous vehicles has been studied by several scholars, who have investigated a number of critical issues.[20] Especially noteworthy is the argument that the full deployment of driverless cars will shift the liability risk from individuals to the vehicle.[21] This entails a twofold effect in terms of negligent behavior. On the positive side, it may reduce the possibility of negligent harm given by, for instance, dangerous driving, as well as the likelihood of "unavoidable accidents",[22] that is the expected harm that the actor could not have foreseen or prevented by exercising reasonable precaution. On the negative side, the adoption of automated vehicles may result in an increase in negligent behavior due to an over-reliance on the technology. Such ambiguity leads to the question on how to apportion liability between actors and which regime would be more suitable. Should a strict liability regime be applied, thus relieving operators from liability costs?

A second matter of interest concerns the allocation of liability and its impact on innovation. The relocation of liability from the driver to the product (*i.e.* the car manufacturer) might have a "chilling effect" on innovation, as putting the burden of liability on the manufacturer would lead

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[19] Israel Gilead, 'Tort Law and Internalization: The Gap between Private Loss and Social Cost' (1997) 17 International Review of Law and Economics 589.

[20] F Patrick Hubbard, 'Allocating the Risk of Physical Injury from "Sophisticated Robots": Efficiency, Fairness, and Innovation', *Robot law* (Edward Elgar Publishing 2016); Gary E Marchant and Rachel A Lindor, 'The Coming Collision between Autonomous Vehicles and the Liability System' (2012) 52 Santa Clara L. Rev. 1321; Cesare Bartolini, Tamás Tettamanti and István Varga, 'Critical Features of Autonomous Road Transport from the Perspective of Technological Regulation and Law' (2017) 27 Transportation Research Procedia 791; Andrea Bertolini and Massimo Riccaboni, 'Grounding the Case for a European Approach to the Regulation of Automated Driving: The Technology-Selection Effect of Liability Rules' [2020] European Journal of Law and Economics 1; Steven Shavell, 'On the Redesign of Accident Liability for the World of Autonomous Vehicles' (2020) 49 The Journal of Legal Studies 243; Maurice Schellekens, 'Self-Driving Cars and the Chilling Effect of Liability Law' (2015) 31 Computer Law & Security Review 506.

[21] See, for instance: Bartolini, Tettamanti and Varga (n 20).

[22] See Mark F Grady, 'Unavoidable Accident' (2009) 5 Review of Law & Economics <https://www.degruyter.com/view/j/rle.2009.5.1/rle.2009.5.1.1302/rle.2009.5.1.1302.xml>. In his contribution, Grady distinguishes between unavoidable accidents, namely the inevitable risk that persists when a party has used due care (*e.g.* an object appearing in front of the car), and negligent harm, where due care would have avoided the accident. In this perspective, under strict liability the injurer is liable for both negligent harm and unavoidable accident, whereas under negligence the injurer is liable only for negligent harm. Grady contends that modern safety technologies paradoxically increase the possibility of negligent harm.

to more uncertainty and might hinder firms' willingness to invest in risky technologies.[23] On this aspect, Porter contended that the product liability system in the US was so much uncertain to delay innovation, and he called for its structural renovation.[24] Galasso and Luo assert that the idea that excessive liability may retard innovation has even shaped high-level case law such as the 2008 Riegel v. Medtronic Supreme Court decision.[25,26] The same scholars explore the effects of liability risk on innovation incentives. They demonstrate that increased liability risk reduces innovation incentives for new technologies that are riskier than the current technology but encourages the development of new technologies that are safer.[27] It has been argued that the existing civil liability regime might disincentivize firms from investing in the development of AI technologies.[28] Such criticisms are not new, as many contributions in the legal and economic literature have questioned the effects of liability on R&D investments in safety technologies in many fields, but above all with regard to medical liability. In this respect, when liability is concerned, both AI and healthcare share similar incentives and externalities.[29]

An additional effect to consider is the impact of the liability regime on product's safety, which is deeply intertwined with the uncertainty surrounding automated vehicles. AI-based cars entail intrinsic *unknown risks*, namely factors leading to potential accidents that are unknown by both the manufacturer and the end-user. Such unknown risks are intrinsically linked to what Calo calls "emergence" of AI systems, namely the unpredictability of their interaction with the environment.[30] Law and economics scholars have advanced the hypothesis of imposing liability for unknown risks.[31] According to Faure et al., "whether liability for unknown risks is desirable depends on what is more important: avoiding the marketing of products which are not (yet)

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[23] Gideon Parchomovsky and Alex Stein, 'Torts and Innovation' (2008) 107 Mich. L. Rev. 285; Peter Huber, 'Safety and the Second Best: The Hazards of Public Risk Management in the Courts' (1985) 85 Columbia Law Review 277; Alberto Galasso and Hong Luo, '20. Punishing Robots: Issues in the Economics of Tort Liability and Innovation in Artificial Intelligence', *The Economics of Artificial Intelligence* (University of Chicago Press 2019).

[24] Michael E Porter, 'The Competitive Advantage of Nations' (1990) 1 Competitive Intelligence Review 14.

[25] Riegel v. Medtronic, Inc., 552 U.S. 312 (2008).

[26] Galasso and Luo (n 23).

[27] ibid.

[28] See, among others, Erica Palmerini and Andrea Bertolini, 'Liability and Risk Management in Robotics' (Nomos Verlagsgesellschaft mbH & Co KG 2016); W Kip Viscusi and Michael J Moore, 'Product Liability, Research and Development, and Innovation' (1993) 101 Journal of Political Economy 161; Andrea Bertolini, 'Robotic Prostheses as Products Enhancing the Rights of People with Disabilities. Reconsidering the Structure of Liability Rules' (2015) 29 International Review of Law, Computers & Technology 116; Maria Lillà Montagnani, 'Liability and Emerging Digital Technologies: An EU Perspective' forthcoming in Notre Dame Journal of International & Comparative Law, Volume 11 <https://www.academia.edu/43696325/Liability_and_emerging_digital_technologies_an_EU_perspective>; Alberto Galasso and Hong Luo, '20. Punishing Robots: Issues in the Economics of Tort Liability and Innovation in Artificial Intelligence', *The Economics of Artificial Intelligence* (University of Chicago Press 2019); European Commission, 'White Paper on Artificial Intelligence: A European Approach to Excellence and Trust' (*European Commission - European Commission*, 2020) <https://ec.europa.eu/info/files/white-paper-artificial-intelligence-european-approach-excellence-and-trust_en>.

[29] William J Gaine, 'No-Fault Compensation Systems: Experience Elsewhere Suggests It Is Time for the UK to Introduce a Pilot Scheme'.

[30] Emergence is essential to define to what extent autonomous vehicles actions can be foreseen and how liable other people should be for them. See Ryan Calo, 'Robotics and the Lessons of Cyberlaw' [2015] California Law Review 513.

[31] Michael Faure, Louis Visscher and Franziska Weber, 'Liability for Unknown Risks–A Law and Economics Perspective' (2016) 7 Journal of European Tort Law 198.

safe enough, or not hindering the introduction of better new products".[32] On the one hand, imposing liability for unknown risks could persuade the producer to invest in safer technologies.[33] On the other, fears of liability for hidden risks in the new products may disincentivize firms' investments in new products and the commercial release of existing products that may suffer from unknown risks.[34] It follows that the desirability of liability for unknown risks cannot be established a priori and will eventually depend on the features of the product.[35]

In summary, more autonomy in vehicles implies less agency for the human driver, hence from an economic efficiency perspective the liability risk will be allocated on the vehicle itself, that is to say autonomous vehicles will be subject to product liability. This entails significant consequences for firms' investments in newer technologies. The next section explores the role of the tort system in balancing parties' incentives under the framework of the economic analysis of law, looking at compliance efforts and human negligence.

1.3.3 Durable precautions, compliance-saving technologies and the role of human negligence

In tort law, in order to avoid harming others, potential injurers are encouraged to invest in optimal precautions. Negligent behavior occurs if the injurer fails to take the level of precaution that a reasonable person would take to avoid such harm. However, not all precautions are the same. Grady distinguishes between *durable* and *non-durable* precautions.[36] Precautions are durable if they are long lasting and require a single isolated measure to be taken. Vice versa, non-durable precautions are taken per unity of activity and must be frequently taken.[37] AI technologies in connected cars can be considered as durable precautions. By purchasing the automated car, which is bought one time and lasts over time, the consumer reduces the expected cost of accident. Similarly, by researching, developing and testing a safer technology, the manufacturer reduces the expected cost of accident.

However, connected vehicles can be further analyzed by looking at their influence on durable and non-durable precautions. In fact, a new technology can have a two-fold effect on the level of durable and non-durable precaution. It can either save compliance efforts (*compliance-saving technology*) or increase them (*compliance-using technology*).[38] Such categorization can be applied to driverless cars. As shown in the figure below, in the early stage of deployment, when on the road, autonomous vehicles will drive faster, hence the safety driver should pay more attention in case something unexpected appears in the way (increased compliance effort by the human operator). As the level of autonomy increases, the human backup driver will have less control over the technology, therefore her compliance efforts will decrease. Also, given the novelty and sophistication of the technology, automated driving systems will probably undergo

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[32] ibid.

[33] William M Landes and Richard A Posner, 'A Positive Economic Analysis of Products Liability' (1985) 14 The Journal of Legal Studies 535.

[34] Huber (n 23).

[35] Faure, Visscher and Weber (n 31).

[36] Mark F Grady, 'Why Are People Negligent Technology, Nondurable Precautions, and the Medical Malpractice Explosion' (1987) 82 Nw. UL Rev. 293.

[37] Francesco Parisi, *The Language of Law and Economics: A Dictionary* (Cambridge University Press 2013).

[38] Grady (n 22).

a more severe and frequent level of control by the manufacturer (increased compliance effort by the manufacturer). In other words, self-driving vehicles will be likely to require more compliance efforts from both the manufacturer and the end-user in a partial automation scenario, that is to say they are compliance-using technologies. Under the borderline scenario of full automation, however, they will change from compliance-using to compliance-saving technology for the operator.

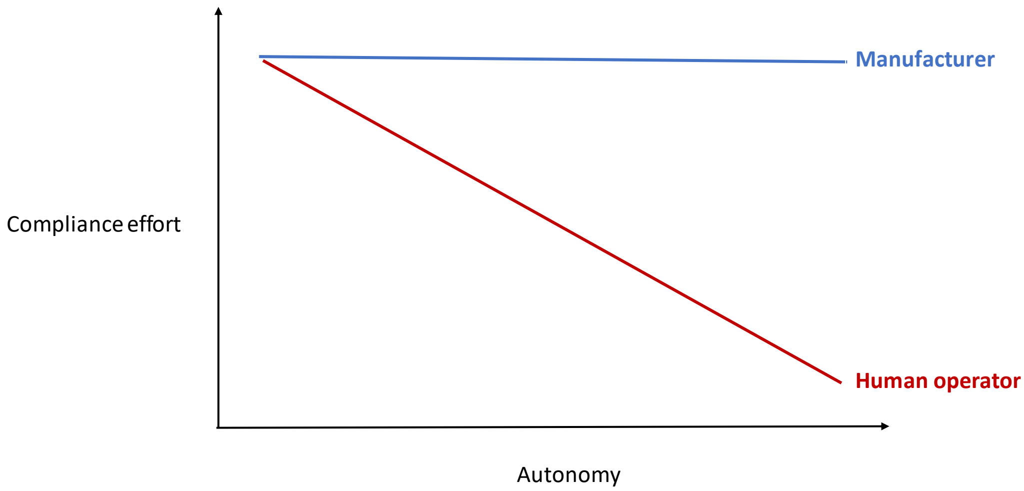

Figure 1 Compliance efforts in relation to the autonomy levels of automated vehicles

Grady expands his analysis by arguing that compliance-using technologies increase the opportunity for negligent behavior for end-users.[39] To explain this argument and test its applicability to the field of autonomous cars, it is worth referring to a sector that has already witnessed a technological shift, namely aviation.

In her research on human control in proto-automation settings, Elish analyzed the history of accidents involving cruise control and autopilot systems in aircrafts from 1950s to nowadays.[40] She found that while the flight control gradually shifted from the pilot to the software, the attribution of responsibility remained focused on the figure of the pilot. According to her findings, the nearest human operator was blamed for the accident even in cases where he was disempowered by the system. Elish introduced the concept of "moral crumple zone" to describe how human operators are consistently blamed for negligence in cases where they have a limited control over the behavior of an automated vehicle.[41] In these situations, just as the crumple zone in a car is designed to absorb the force of impact in a crash, the human driver might become the accidental or intentional element bearing the cost of the moral and legal responsibility when the overall system fails. Likewise, as illustrated in the Uber crash as well as in other accidents involving semi-autonomous vehicles, human backup drivers are frequently found at fault, even when there is a malfunctioning in the algorithm contributing to the crash. Thus, when the level of autonomy of the vehicle is limited (*i.e.* Level 2, 3 and 4)

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[39] ibid.

[40] Madeleine Clare Elish and Tim Hwang, 'Praise the Machine! Punish the Human! The Contradictory History of Accountability in Automated Aviation' [2015] Punish the Human.

[41] Madeleine Clare Elish, 'Moral Crumple Zones: Cautionary Tales in Human-Robot Interaction' (2019) 5 Engaging Science, Technology, and Society 40.

operators are becoming the moral crumple zone of AI-driven accidents, replicating the mechanisms occurred in other sectors which experienced automation. It seems that, despite playing a crucial role in these tragic events, technology is spared from the blame. According to Elish, such behavior is caused by the social tendency to underestimate human abilities and overestimate machines performance.[42] While it seems reasonable to hold humans accountable, her argument runs, the "human error" invoked in case of wrongdoings mostly refers to the safety driver, not to the developer of the algorithm.

1.3.4 Liability on the manufacturer or on the operator? A closer look at the incentives

As the level of autonomy in automated vehicles increases, the extent to which operators can take precautions decreases, since their level of control over the driving system gradually diminishes. Consequently, as argued above, according to a pure economic analysis of law perspective, the burden of liability is expected to shift to the manufacturer, who is in the best position to control the intrinsic risk of the activity. In other words, the manufacturer is the cheapest cost avoider.[43] This implies significant consequences for producers' investments in precautions.

Manufacturers could take precautions by redesigning the vehicle components in such a way that the backup operator would not be easily distracted. In case of semi-automated vehicles, as demonstrated by the Uber crash, when human supervision is still required, if the backup driver is not actively engaged in driving, she may take not enough precautions and over-rely on the technology. In this respect, so far, car producers have given mixed messages about safe driving when marketing their products. Tesla, for instance, has put a console game on its self-driving car, implicitly alluding to the possibility of doing something else during the drive. On the other hand, if a manufacturer of autonomous cars puts the human operator in the driver seat and expects her to not do anything while at the same time does not allow her to get distracted, it does not make much sense either.

A further consideration must be made on incentives to transparency for manufacturers. Producers of automated vehicles should invest in transparency of their algorithms as well as their data recording capability in order to facilitate the investigations in case of accident. This means designing codes that are clear, readable and verifiable by courts and experts. In this respect, manufacturers typically lack such incentives. In fact, developers of algorithms face a dilemma. On the one hand, they aim to write a code that is clean, understandable and clear in case they need to change it, replicate it, re-use it or extend it. On the other hand, the business pressure pushes programmers to write software in a fast manner, which allows to sell more and outrun competitors, but not always results in a code that is understandable and flawless. In this case, a transparency obligation could serve as a potential solution.

As regards the level of risk created by the activity, thanks to the automated driving technology, cars will drive faster, therefore it will be harder for people walking across the street to avoid them. Due to this increased number of potential encounters, the manufacturer of the car will be incentivized to increase the level of safety on the car, which might involve a better training of the algorithm, as better trained algorithms are more capable to detect and better classify objects or predict unexpected events.

In order to incentivize operators to take sufficient precautions, however, a fault-based liability system could be maintained, or, in alternative, to encourage investments in precautions, an

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[42] ibid.

[43] Calabresi (n 18).

alternative system (*e.g.* a special driving license) could be envisaged. Some authors argue that assigning liability to users may incentivize manufacturer innovation, as consumers would require safer and user-friendly design characteristics and, if mandatory training was introduced, "easier to teach" designs could reduce adoption costs.[44]

1.3.5 Liability on the AI: the legal personality hypothesis

Finally, liability could be allocated to the AI system itself instead of the manufacturer or the driver. In order to do so, the AI should be considered as a distinct ontological category endowed with legal capacity, as in the case of corporations. The hypothesis of e-personhood for robots has been explored by both academics and policymakers. In 2017, the Resolution by the European Parliament on Civil Law Rules on Robotics opened the debate at the political level, affirming the possibility of "creating a specific legal status for robots in the long run, so that at least the most sophisticated autonomous robots could be established as having the status of electronic persons responsible for making good any damage they may cause, and possibly applying electronic personality to cases where robots make autonomous decisions or otherwise interact with third parties independently".[45] The rationale behind the proposal was to isolate the obligations of the algorithm from those of producers and developers in case of accidents caused by an independent decision taken by the AI. In short, giving a distinct personality to the machine could solve the problem of a "fair and efficient allocation of loss", as stressed by the Expert Group on Liability and New Technologies.[46] The Parliament proposal revamped an old legal and ethical debate over the personalization of machines, in particular when they display an autonomous behavior.[47]

In the scholarly debate, two lines of thought can be identified, namely researchers against and in favor of the attribution of legal personality to AI systems. When it comes to the opponents of an e-personhood, they claim that using legal personality as a solution to impute liability and thus isolate robots' obligations from those of manufacturers and developers would lead to moral hazard and attempts to circumvent the rules by victims. Experts in robotics and artificial intelligence openly criticized the Parliament's proposal by signing an open letter in which they solicited the European Union to opt for a different strategy.[48] According to the group of experts, disregarding ethical and technical arguments, from a legal point of view there are at least three

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[44] Galasso and Luo (n 23).

[45] 'Resolution of 16 February 2017 with Recommendations to the Commission on Civil Law Rules on Robotics (2015/2103(INL))' (2017) <https://www.europarl.europa.eu/doceo/document/TA-8-2017-0051_EN.html>. Paragraph 59.

[46] European Commission. Directorate General for Justice and Consumers., *Liability for Artificial Intelligence and Other Emerging Digital Technologies.* (Publications Office 2019) <https://data.europa.eu/doi/10.2838/573689>.

[47] The issue of legal personality of AI has been discussed by, among others, Jiahong Chen and Paul Burgess, 'The Boundaries of Legal Personhood: How Spontaneous Intelligence Can Problematize Differences between Humans, Artificial Intelligence, Companies and Animals' (2019) 27 Artificial Intelligence and Law 73; Christophe Leroux and Roberto Labruto, *A Green Paper on Legal Issues in Robotics* (2012); Lawrence B Solum, 'Legal Personhood for Artificial Intelligences' (1991) 70 NCL Rev. 1231; Robert van den Hoven van Genderen, 'Do We Need New Legal Personhood in the Age of Robots and AI?', *Robotics, AI and the Future of Law* (Springer 2018).

[48] The open letter signed by 156 experts reads "The creation of a Legal Status of an "electronic person" for "autonomous", "unpredictable" and "self-learning" robots is justified by the incorrect affirmation that damage liability would be impossible to prove. From a technical perspective, this statement offers many bias based on an overvaluation of the actual capabilities of even the most advanced robots, a superficial understanding of unpredictability and self-learning capacities and, a robot perception distorted by Science-Fiction and a few recent sensational press announcements." 'Robotics Openletter | Open letter to the European Commission' <http://www.robotics-openletter.eu/> .

reasons why robots should not be granted legal personality. First, basing robots' legal status on the natural person model would guarantee human rights to AI-agents, including the right to integrity and dignity, which would contradict the Charter of Fundamental Rights of the European Union and the Convention for the Protection of Human Rights and Fundamental Freedoms. Second, "robots' legal status cannot derive from the legal entity model, as it would imply the existence of human persons behind the legal person to represent and direct it", and this is not the case for robots. Third, the Anglo-Saxon model of Trust is not a practicable solution either, given its complexity and the need for a human as a last resort trustee to manage the robot. A number of scholars[49] and political entities[50] echoed such skepticism. In particular, Bryson et al. argue that "difficulties in holding "electronic persons" accountable when they violate the rights of others outweigh the highly precarious moral interests that AI legal personhood might protect".[51] In the same vein, splitting a company whose products or services are AI-based into electronic persons would vastly amplify the existing phenomenon of the over-extension of legal personality leading to misconducts (such as in case of shell companies used for money laundering).[52]

On the contrary, the boosters of the e-personhood hypothesis argue that it would help overcome several challenges that the doctrinal law is faced with as occurred in the past with companies. In fact, the concept of granting personality to non-human subjects is not new. This legal fiction is being used in corporate settings since the Industrial Revolution, where the pace of industrial progress required a more efficient separation between ownership and control. This led to the establishment of the modern limited liability company, which allowed investors to confine their responsibility in the event of business failure to the amount they invested in the company. The creation of the firm as a separate legal entity serves a threefold purpose, namely coordinating parties interests instead of contracts, separate assets thus limiting liability of the firm and, finally, for fiscal purposes. Under such premises, AI systems with legal personality would no longer be property of the manufacturer but they would be tied to it by

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[49] See, among others, A Amidei, 'Robotica Intelligente e Responsabilità: Profili e Prospettive Evolutive Del Quadro Normativo Europeo' (2017) 63 Intelligenza artificiale e responsabilità, Giuffrè; Ugo Ruffolo (ed), *Intelligenza Artificiale e Responsabilità: Responsabilità 'Da Algoritmo'?, A.I. e Automobili Self-Driving, Automazione Produttiva, Robotizzazione Medico-Farmacuetica, A.I. e Attività Contrattuali, Le Tendenze e Discipline Unionali: Convegno Del 29 Novembre 2017, Università per Stranieri Di Perugia* (Giuffrè Editore 2017); Joanna J Bryson, Mihailis E Diamantis and Thomas D Grant, 'Of, for, and by the People: The Legal Lacuna of Synthetic Persons' (2017) 25 Artificial Intelligence and Law 273; SM Solaiman, 'Legal Personality of Robots, Corporations, Idols and Chimpanzees: A Quest for Legitimacy' (2017) 25 Artificial Intelligence and Law 155; Emiliano Marchisio, 'In Support of "No-Fault" Civil Liability Rules for Artificial Intelligence' (2021) 1 SN Social Sciences 1; Giorgia Guerra, *La sicurezza dei prodotti nell'era della robotica: profili di diritto europeo e comparato* (Il Mulino 2018).

[50] The European Economic and Social Committee contended that «the introduction of a form of legal personality for robots or AI», as it believed that such solution «would hollow out the preventive remedial effect of liability law», since «a risk of moral hazard arises in both the development and use of AI and it creates opportunities for abuse». See: European Economic and Social Committee, 'Artificial Intelligence–The Consequences of Artificial Intelligence on the (Digital) Single Market, Production, Consumption, Employment and Society' (2017) Opinion.

In the same vein, in 2019, the members of the Expert Group on Liability and New Technology expressed their doubts about legal personality, arguing that the harm caused by autonomous technologies can be reduced to risks attributed to natural persons or existing legal entities, hence there would not be any need for a new category of legal person. The Expert Group claimed that since AI with a distinct legal personality would be endowed with assets or income, this would result in putting a cap on liability and, as a consequence, it would lead to attempts to circumvent the restrictions to pursue claims against the natural or legal persons to whom the AI can be attributed. European Commission. Directorate General for Justice and Consumers. (n 46).

[51] Bryson, Diamantis and Grant (n 49).

[52] Solaiman (n 49).

means of a contract. In general, advocates of e-personhood claim that the use of analogy might be a solution to overcome the uncertainty deriving from emergent technologies.[53] In the case of AI systems, besides company law, one could resort to various legal domains such animal law or minor law. Some commentators have suggested to consider AI systems as animals. Shaerer et al. contend that robots can be analogized to animals when attributing responsibility in case of accidents.[54] Similarly, Cofone argues that self-driving cars ought to be treated as domesticated animals insofar they have low autonomy and low social valence.[55] Other authors assert that as autonomy increases, strict liability is not a suitable regime, thus robots should be treated as children, ignorant of social norms but capable of learning how to comply with them.[56]

While e-personhood could be suitable in certain situations on a functional basis,[57] it is debatable whether it would be effective in a tort setting. While this legal fiction works for corporations, which are endowed with separate assets and generate profits, in case of autonomous vehicles it would not relieve the manufacturer or the owner from the potential disbursements for damages and insurance. In other words, holding the AI system liable would represent an additional layer of complexity without solving the liability dilemma. Humans (whether drivers or manufacturers) will still have to face the consequences of the AI actions. Furthermore, while for corporations the threat of monetary sanctions works as a deterrent for human managers who might adopt an opportunistic behavior, given its lack of consciousness, AI systems would be not responsive of any incentive. Deterrence under liability takes effect only in presence of moral agency, namely the capability of discerning right and wrong as well as the consequences of one's actions. In this respect, machines have limited moral agency and are not able to able to connect their actions to the possibility of being punished, hence they are insensitive to deterrence.

1.4 Conclusion

The analysis carried out so far highlights that existing studies on automated technologies and in particular connected vehicles focus primarily on fully autonomous agents, underestimating the transitional phase where human operators exert some control on the activity. More specifically, models in the economic analysis of torts do not consider partially autonomous technologies, instead they assume that human operators and technology are substitutes, thus ignoring levels of precautions and activity in semi-autonomous settings.

So far, technical difficulties combined with regulatory uncertainty have led to what could be defined as the false promise of a driverless revolution. A potential effect of the uncertainty arising from attributing liability in case of semi-autonomous vehicles could be that companies bypass the semi-autonomous scenario and opt for fully autonomous vehicles. Moreover, the hybrid scenario involving Level 2 or 3 vehicles would require a reexamination of how cars are designed in order to stimulate backup drivers' attention. The choice of the liability regime

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53 Ignacio N Cofone, 'Servers and Waiters: What Matters in the Law of AI' (2018) 21 Stan. Tech. L. Rev. 167.

54 Enrique Schaerer, Richard Kelley and Monica Nicolescu, 'Robots as Animals: A Framework for Liability and Responsibility in Human-Robot Interactions', *RO-MAN 2009 - The 18th IEEE International Symposium on Robot and Human Interactive Communication* (IEEE 2009) <http://ieeexplore.ieee.org/document/5326244/>.

55 Cofone (n 53).

56 Edmund MA Ronald and Moshe Sipper, 'Intelligence Is Not Enough: On the Socialization of Talking Machines', *The Turing Test* (Springer 2003).

57 In a scenario where AI was granted legal personality, for instance, it could be registered and identified by an ID and potentially endowed with assets. Such possibility could apply in contractual settings, for example in case of chatbots signing contracts with other chatbots (machine to machine contracts).

varies depending on how we conceive AI systems in the first place. Basing the choice of the liability framework on the understanding of AI agents as fully autonomous agents would draw an unrealistic picture of the state of the technology and would underestimate the role of operator's level of care. Clarity and transparency in the code could help facilitate the detection of who is at fault in case of accidents or in case of data breaches. As a consequence, it is of the utmost importance that governments set the right standards and encourage firms to adopt more transparent strategies on how their algorithms function.

Furthermore, the "human in the loop" factor could be considered also in an early stage of the technology development. In the NTSB report on Uber, for instance, it seems that engineers had not envisaged to classify pedestrians outside the walkways. In that case, adding a feedback session with other human agents when training the algorithm could have reduced the risk of a wrong design of the algorithm. Finally, uncertainty is a feature that cannot be disregarded when designing liability rules for AI, and the human factor should be also taken into account.

It is undeniable that the full deployment of autonomous vehicles will depend heavily on the regulatory developments of the coming years. Manufacturers' incentives to mass produce such products are linked to the extent of legal certainty surrounding AI systems. From the perspective of automated technologies and in particular connected cars, a centralized *ex ante* regulatory framework could help reduce the degree of uncertainty[58] on the liability risk by defining safety standards and allowing companies to market only safe products. At the European Level, *ex ante* regulation for certain AI-based technologies such as automated vehicles would also allow for a harmonization of national regimes, speeding up the process of adoption of the technology. Less regulatory uncertainty would in turn incentivize investments in research and development.

At the same time, however, given the fast pace of advancement in AI, *ex ante* regulation might fail to set adequate standards because obtaining information on a technology that is constantly evolving is a costly and time-consuming process. Furthermore, as argued by Shavell, the tort system is cheaper because it incurs costs only when a case is brought, while the establishment of safety requirements under *ex ante* regulation entails higher costs.[59] Applying this argument to connected cars, one might advance the hypothesis that given the expected drop in the number of accidents due to automation, fewer cases will be brought to courts, hence a tort system would be preferable. However, such hypothesis does not take into account the transitionary phase of deployment of partially automated vehicles, in which operator's lack of precaution (due to an over reliance on the driving system) could lead to an increase in the number of accidents. At any rate, regulators should consider that regulation and tort law are complementary systems and, when possible, should be used jointly.[60]

Finally, an additional proposal may rely on mandatory insurance, which is the default set up for traditional vehicles and would isolate the manufacturer from liability issues. Some argue that in an ideal scenario where fully autonomous vehicles benefit from an optimal level of safety there might not be need for a motor insurance.[61] However, as stressed before, some level of risk

[58] For an economic analysis of the trade-off between rules and standards see Louis Kaplow, 'Rules versus Standards: An Economic Analysis' (1992) 42 Duke Lj 557.

[59] Steven Shavell, 'A Model of the Optimal Use of Liability and Safety Regulation' (1984) 15 The RAND Journal of Economics 271.

[60] ibid.

[61] Ronald Leenes and others, 'Regulatory Challenges of Robotics: Some Guidelines for Addressing Legal and Ethical Issues' (2017) 9 Law, Innovation and Technology 1; Palmerini and Bertolini (n 28).

will remain, as a number of unavoidable accidents will occur, and vehicles will still require insurance against theft and any damage. While insurance could be considered as an option once the technology is mature and reaches a critical mass, in the early stages of deployment it may not be an advisable choice because of a lack of data on the likelihood and nature of risks and damages. Also, one should consider that there might be high premiums to pay against high liability risks, discouraging the entry of smaller players.

This paper shed some light on the costs and benefits of self-driving vehicles and the possible incentives created by different liability regimes. An integrated approach to AI-driven accidents involving both *ex ante* regulation and *ex post* tort law could help achieve an efficient system which would allow to tackle the challenges brought by automated vehicles.

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