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ACCIDENT LAW: AN EXCESSIVE STANDARD MAY BE EFFICIENT

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Abstract

In a world with risk-neutral agents, liability rules will only induce efficient behaviour if these rules impose the full (marginal) costs of an action on the parties. However, institutional restrictions or bilateral activity choices can prevent the full internalisation of costs. A mechanism is proposed which guarantees an efficient outcome: monetary fines which are not related to the occurrence of an accident. Such a mechanism requires individuals to violate the standard of care in order to trigger fine payments. Hence, efficiency needs an excessive standard.

JEL Classification: K13, K42.

Keywords: accident law, activity, care, efficiency, fines, standards of care, tort law.

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1. Introduction

A liability rule is a legal regulation which specifies how damages from an accident are allocated among the parties involved. The economic analysis of accident law has shown that liability rules can induce efficient behaviour if these rules assign the full costs of an individual's action to this agent. In such a case, all externalities which could distort decisions in the absence of a liability rule are internalised.[1] However, commonly found liability rules may fail on this efficiency requirement. If, for example, the probability of having to pay for damages, given an accident, is less than unity in a setting with unilateral choices, the internalisation will be incomplete. Moreover, in a setting of bilateral care and activity choices a liability rule cannot generally allocate accident costs in such manner as to impose the full costs on both parties simultaneously. To correct for the inefficiency, broadly speaking, two approaches have been suggested: first, a payment due to a liability rule is combined with a fine in the case of an accident. This fine has to exactly compensate for the accidents costs not born. Second, a negligence rule can induce adherence to an efficient level of care while tax-like payments provide incentives for efficient activity choices.

In this paper, a further mechanism is proposed which guarantees an efficient outcome: monetary fines which are *not* related to the occurrence of an accident. The decisive aspect is that for these fines to be incurred, individuals must violate a standard of care which triggers fine payments. If the standard is represented by the efficient level of care, optimal care choices will not warrant this requirement. Hence, the standard of care must be excessive. This mechanism for inducing efficient behaviour has a central advantage - it can be observed, as for example in the case of road traffic. This is a typical occupation with bilateral care and activity choices. In such a setting, common liability rules which simply divide damages cannot induce efficient outcomes. Instead, virtually all countries know fines, for example, for speeding, parking offences, or jaywalking which have to be paid in the absence of an accident. The model presented below can explain their existence. These non-accident related fines are akin to 'act-based' sanctions (Shavell 1993, Polinsky and Shavell 2000). The analysis demonstrates that a combination of act- and harm-based payments can be used to induce efficient outcomes, but that efficiency requires an inefficient standard of care in a world of bilateral activity choices.

Section 2 presents a simple model of bilateral choice and shows why liability rules cannot generally imply the efficient outcome. The solutions which have been proposed in the literature to remedy this feature are discussed. Since these solutions have often been debated in the context of road traffic, this example is also used in the present paper. Section 3 analyses how fines which are independent of the occurrence of an accident can induce risk-neutral drivers to behave efficiently. Focusing on a setting with unilateral care and activity choices

[1] While a rule of strict liability imposes the full marginal and total costs of an action on a party, a negligence rule assigns the full costs of an accident to a party only at a specific level of care. While efficiency may only require the internalisation of marginal costs (Wittman 1981), subsequently, reference is made to the full costs.

allows to bring out the intuition for the efficiency result most clearly. However, the necessity to combine liability rules with non-accident related fines in order to induce an efficient outcome is most compelling in a world with bilateral activity choices. Therefore, an appendix demonstrates that an efficient outcome can be obtained in a world of bilateral care and activity decisions. Section 4 considers two extensions to the basic approach: risk-aversion and punitive damages. Section 5 discusses the (dis-) advantages of non-accident related fines relative to other mechanisms for achieving efficiency.

2. The Problem of Bilateral Care and Activity Choices

Suppose a certain type of action - such as participating in road traffic - might cause accidents which impose costs not only on the party performing the task but also on others. If only one driver can choose his level of activity and care, an efficient outcome can be obtained if this driver bears the full costs of his activity. A system of strict liability can, therefore, induce an efficient outcome. Fines for the violation of standards are not required in order to achieve efficiency. If there is another driver who can also choose her level of care, strict liability for the first driver will imply that the second driver does not have to bear any of the costs of an accident. The efficient level of care by the second type of driver can be obtained by introducing a contributory negligence clause. Once again, fines are not needed to obtain efficiency. However, if the second driver can vary activity but avoid all liability by adhering to the standard of care, she will not take into account the variation in expected accident costs due to her choice of activity. Since liability rules do not condition payments on activity, they cannot induce efficient behaviour in a world of bilateral activity choices (Shavell 1980, 1987). Efficient outcomes can only be achieved if risk-neutral drivers bear the full costs of their choices. In effect, a rule of double strict (marginal) liability is required, given that the behaviour of a particular driver does not affect the probability that an accident occurs between two other drivers.[2]

Accordingly, efficiency requires the use of an instrument in addition to a liability rule. Double liability could be achieved if drivers were fined the difference between the actual damage and the costs which they bear. Thus, the fine which induces efficient behaviour would only have to be paid in the case of an accident and it would have to reflect the division of damages between the drivers involved. However, actual fines, for example in the context of road traffic, depend on care levels and not on cost sharing rules. Instead of fines, (Pigouvian) taxes could be used to impose the full costs of the activity. Such taxes would have to be a function of care and

[2] Cf. Hindley and Bishop (1983) or de Meza (1986). de Meza (1986) shows that Shavell's (1980, 1987) claim, according to which there cannot be a liability rule for situations of bilateral activity choices which induces the efficient outcome, does not always hold. Assume that the activity of driver 1 depends negatively on the activity of driver 2, and vice versa, and that each driver takes the behaviour of the other as given. Individual behaviour would then result in the efficient outcome if the excessive activity due to incomplete liability were exactly balanced by the insufficient activity owing to the activity choices of the other drivers. Clearly, this outcome only occurs by chance.

activity. An alternative mechanism to achieve efficient outcomes would be a dual negligence rule, combined with activity-related payments. In the context of road traffic such payments could be surcharges on insurance premiums, extra petrol taxes, or road user charges.[3]

To formalise the above ideas, suppose that there are two groups of risk-neutral agents, referred to as drivers 1 and 2. All drivers within each group are identical. The groups are sufficiently large such that potential accident victims do not know each other in advance. Moreover, each individual driver takes the behaviour of others as given. Drivers face different gains or costs from driving and, therefore, select distinct levels of care and activity. Let the monetary equivalent of the gain for driver 1 resulting from an activity level z and a choice of care denoted by x be given by G(x, z). G is strictly concave in the activity z and reaches a maximum for some finite level. Moreover, G declines with care at a non-decreasing rate since higher care implies a greater expenditure, and the greater the care level is, the more expensive an additional unit of care might become. Finally, the gain from driving will be zero if care attains its maximum level x_{max}. The gain for driver 2 is denoted Γ and exhibits the same features as that of driver 1. These assumptions are summed up in table 1:

Table 1: Features of the drivers' gain functions

	Gain of driver 1 G(x, z)	Gain of driver 2 Γ(y, u)
Care: x, y	$G_x < 0$, $G_{xx} \leq 0$, $G(x_{max}, z) = 0$	$\Gamma_y < 0$, $\Gamma_{yy} \leq 0$, $\Gamma(y_{max}, u) = 0$
Activity: z, u	$G_z(x, \tilde{z}) = 0$, $G_{zz} < 0$ $G_z > (<)\ 0$ for $z < (>)\ \tilde{z}$	$\Gamma_u(y, \tilde{u}) = 0$, $\Gamma_{uu} < 0$, $\Gamma_u > (<)\ 0$ for $u < (>)\ \tilde{u}$

Given care and activity choices of x, y, z, u, expected damages D = D(x, y, z, u) arise. Damages decrease with care at a decreasing rate, D_x, $D_y < 0$, D_{xx}, $D_{yy} > 0$, and increase with activity choices at an increasing rate D_z, $D_u > 0$, D_{zz}, $D_{uu} > 0$. One can think of drivers 1 and 2 as 'injurers' and 'victims', respectively, such that expected damages D(x, y, z, u) only affect one driver directly. However, this simplification is not required for the subsequent analysis of risk-neutral drivers, as long as also the 'injurer's' damages are covered by the liability rule (Arlen 1990). Furthermore, and in contrast to the assumptions of the model, accidents can involve more than two parties. Such multy-party accidents could also be integrated into the present framework by redefining D(x, y, z, u) as the expected accident costs owing to all types of accidents.

A liability rule assigns a fraction α (1 - α) of expected damages to driver 1 (2), $0 \leq \alpha \leq 1$. For simplicity, strict liability is assumed. The parameter α then describes some institutional regulation of how damages are shared. If another liability rule were in operation, the basic fea-

[3] See Vickrey (1968), Green (1976), Tullock (1981), Landes (1982), Finsinger and Pauly (1990), Litman (1997), or Edlin (1999) for a discussion of various such proposals.

ture of the problem would persist: at least one driver would not have to bear the full expected costs of accidents. This is because a liability rule simply shares damages and does not allow to make damage payments depend on activity levels for all drivers at the same time. For simplicity, the parameter α is not conditioned on the liability rule.

The expected payoff W of the society is the sum of the monetary equivalents of the gains for both drivers less the expected costs of accidents (cf. Shavell 1987):

$$W = G(x, z) + \Gamma(y, u) - D(x, y, z, u) \quad (1)$$

Maximisation of the expected payoff W with respect to x, y, z, u is assumed to yield a unique solution. The efficient levels of care and activity are denoted by x^*, y^*, z^*, and u^*.

Turning to individual decisions, driver 1 maximises his expected payoff W_1, which excludes a fraction $(1 - \alpha)$ of expected damages.

$$W_1 = G(x, z) - \alpha D(x, y, z, u) \quad (2)$$

The payoff W_2 of driver 2 is defined analogously.

$$W_2 = \Gamma(y, u) - (1 - \alpha)D(x, y, z, u) \quad (3)$$

As long as $\alpha < 1$ holds, the levels of care and activity which result from the first driver's maximisation exercises are inefficient. The same consequences apply for driver 2, as long as $\alpha > 0$. Hence, efficiency requires $\alpha(1 - \alpha) = 1$ for $\alpha \in [0, 1]$, which is, therefore, theoretically impossible. These inefficiencies cannot be circumvented by rules which condition liability on the drivers' level of care, as any form of negligence rule does, since there always persists an incentive to choose an inefficient activity level. The central reason for the inability of a liability rule to induce efficient outcomes in a setting with bilateral activity choices is that at least for one driver the private costs of activity changes differ from the respective costs to society; the private costs of additional activity being zero if a care standard is observed (but see footnote 2).

3. A Mechanism to Obtain Efficient Outcomes

Subsequently, a mechanism is derived which induces efficient behaviour by imposing fines on drivers also in the absence of accidents. For this mechanism to achieve the desired results, fine payments have to be incurred even if drivers choose the efficient level of care. Thus, the care standard needs to be excessive. Equations (1) and (2) - or (3) - show that a model of unilateral choice with restrictions on liability is analytically equivalent to an approach with bilateral decisions. In both cases, expected accident costs are not fully internalised. Thus, the mechanism which can be employed to obtain efficiency is illustrated in a setting of unilateral choices, imposing value of $\alpha < 1$. This restriction allows to bring out the central means of inducing efficient behaviour most clearly. However, efficient behaviour in the unilateral choice model can be achieved by abolishing the institutional restrictions on liability, that is setting $\alpha = 1$. This is not feasible in a world of bilateral decisions about activity since full liability cannot be imposed on both drivers simultaneously. Accordingly, the proof that efficiency can be obtained in such a world by the use of non-accident related fines as well is also provided.

In a model of unilateral choices, efficient outcomes are determined by the maximisation of the payoff G(x, z) - D(x, z) due to the actions of driver 1 with respect to x and z. The driver is assumed to be liable for accident costs, given $\alpha < 1$. Moreover, he has to pay a fine when observed violating a care standard. Let the expected fine P be a function of care x and activity z and suppose, in addition, that it is given by $P(x, z) = (1 - \alpha)D(x, z)$. A fine can be conditioned on the level of care if the extent of the violation of the standard is observable. Moreover, the fine can be made a function of the activity level if care choices of higher activity drivers are examined more often than those of their lower activity counterparts.

Given a standard of care s and a fine $P(x, z) = (1 - \alpha)D(x, z)$, the decision rule for driver 1 is:

$$\max_{x,z} \begin{cases} G(x,z) - \alpha D(x,z) - P(x,z) = G(x,z) - D(x,z), & \text{if } x < s \\ G(x,z) - \alpha D(x,z), & \text{if } x \geq s \end{cases} \tag{4}$$

The usual procedure in the analysis of liability rules is to assume that the standard of care s is defined by the optimal level x*. In this setting, however, adherence to a standard of care $s = x^*$ implies that the level of activity z is inefficient.[4] This inefficiency can be overcome if drivers always have to pay the expected fine. Hence, the optimal levels of x and z will be obtainable if drivers can be induced to violate the norm. That such behaviour is indeed observable can be illustrated by the example of speeding. It is quite common that drivers exceed the speed limit such that they will incur a fine if being caught. The basis of this behaviour seems to be the calculation that the expected fine is less than the gain from reaching a destination more quickly. If such considerations determine the choice of care, expected fine payments will be positive.

The only standard s which ensures efficient levels of care $x = x^*$ and of activity $z = z^*$ is a standard s which is impossible to adhere to. In this case, drivers maximise the first line of equation (4). The value of s which guarantees that all drivers ignore the standard s and choose the efficient levels of care x* and activity z* is implicitly defined by two conditions:

$$G(x^*,z^*) - \alpha D(x^*,z^*) - P(x^*,z^*) > G(s,z_s) - \alpha D(s,z_s) \equiv A, \qquad \text{if } x_s^* < s \tag{5a}$$

$$G(x^*,z^*) - \alpha D(x^*,z^*) - P(x^*,z^*) > G(x_s^*,z_s^*) - \alpha D(x_s^*,z_s^*), \qquad \text{if } x_s^* \geq s \tag{5b}$$

where x_s^* and z_s^* result from the maximisation of the second line of (4), and z_s is the optimal activity given adherence to a standard s and (implicitly) defined by $G_z(s, z) - \alpha D_z(s, z) = 0$.

[4] Note that this inefficiency would be more pronounced if instead of strict liability a negligence rule were to prevail since adherence to the standard would then imply expected accident costs of zero.

Condition (5a) deals with the case that the driver's optimal level of care $x_S{}^*$ in the absence of fines is less than the standard, $x_S{}^* < s$. The driver might then maximise his payoff by setting $x = x^*$ or $x = s$. Inequality (5a) states that the socially optimal violation yields a greater payoff than the corner solution ($x = s$, $z = z_S$) and thereby guarantees that the driver benefits from a violation of the standard. The second requirement (5b) covers the case that the optimal level of care in the absence of fines is greater than the standard, $x_S{}^* > s$ and requires that the optimal choices of x and z are preferable to an interior solution in the absence of fines.[5]

The inequality (5b) will no longer represent a restriction if the standard is chosen sufficiently high. Accordingly, if the driver is characterised by an optimal level of care $x_S{}^* \geq s$, this outcome can be prevented by raising s above $x_S{}^*$. By increasing the standard s a driver can always be forced either to select a corner solution ($x = s$, $z = z_S$) or to choose x^*, z^*. To guarantee that the driver violates the standard of care, it remains to be shown that a corner solution $x = s$ is not optimal. A driver who selects a corner solution takes excessive care by assumption. If the standard is raised further, the costs of adherence to the standard will increase more strongly with the level of the standard than the gain from doing so rises since the optimal degree of care has already been exceeded. Eventually there will be a sufficiently high standard which makes it optimal for the driver to violate this norm and to choose care and activity efficiently. Formally, this can be seen from inspection of (5a), where the left hand side is independent of s, since the payoff of a driver who violates the norm is unaffected by variations in the standard s, while the right hand side decreases with s.

$$\left.\frac{dA}{dx}\right|_{x=s} = G_X(s, z_S) - \alpha D_X(s, z_S) + \frac{dz_S}{dx}\{G_Z(s, z_S) - \alpha D_Z(s, z_S)\}$$

$$= G_X(s, z_S) - \alpha D_X(s, z_S) < 0 \qquad (6)$$

Since the driver chooses activity z_S optimally, the expression in curly brackets in (6) is zero. Moreover, because the required standard s exceeds the optimal level of care $x_S{}^*$, the driver, while adhering to the standard, would like to reduce care, implying $G_X - \alpha D_X < 0$. Because the gain G while adhering to the standard s will eventually become zero if the standard approaches the maximum level of care x_{max}, by increasing s it is always possible to reduce the expected payoff of a driver who adheres to this standard. Accordingly, the efficient levels of care and activity can be induced. This result can be summarised as:

Proposition 1

If institutional restrictions prevent full liability in a setting of unilateral care and activity choices by risk-neutral agents, raising the required standard of care sufficiently above the efficient level and fining agents who violate the standard with a positive probability, independently of the occurrence of an accident, can induce efficient care and activity choices.

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[5] Since a driver is fully liable, adherence to the standard does not guarantee that he can avoid accident costs. Hence, it may be optimal for the driver to select a level of care in excess of the standard.

The intuition for Proposition 1 is straightforward: by imposing a standard s which is violated for certain, the fine P effectively acts as an expected activity-related payment. This is because every unit of activity z is executed with a level of care which does not conform to the required standard. If, in addition, the fine P(x, z) mimics the expected costs of an accident, less the fraction α which drivers have to pay themselves, optimal care will be induced.

It has been argued in the introduction that non-accident related fines are more relevant in a setting with bilateral activity choices than in one with unilateral decisions. As indicated, such fines can also induce efficient behaviour in a world with bilateral activity choices. This is the case for an expected fines $P_1(x, z) = D(x, z, y^*, u^*)(1 - \alpha)$ for driver 1 and a fine $P_2(y, u) = D(x^*, z^*, y, u)\alpha$ for driver 2. By conditioning fines on the efficient care and activity levels of the other drivers, the costs which fines internalise only depend on the drivers' own choices. Such fines allow for the following statement:

Proposition 2

In a setting of bilateral care and activity choices by risk-neutral agents, raising the required standard of care sufficiently above the efficient level and fining agents who violate the standard with a positive probability, independently of the occurrence of an accident, can induce efficient care and activity choices.

The proof for Proposition 2 proceeds as follows (for details see the appendix). Assume that driver 2 chooses efficient levels of care and activity u* and y*. Driver 1 then maximises $G(x, z) - \alpha D(x, z, y^*, u^*) + P_1(x, z) = G(x, z) - D(x, z, y^*, u^*)$. This yields the efficient outcomes x* and z*. The same is true for driver 2, given optimal choices by driver 1. Thus, if an equilibrium other than the optimal one exists, it needs to be characterised by choices of care and/or activity which deviate from their efficient levels. It is finally shown that there is no such equilibrium for any possible value of α. Hence, the correct specification of the fine also allows for efficient outcomes in a bilateral care and activity setting.

4. Extensions

In order to evaluate the robustness of the proposition that non-accident related fines can induce efficient behaviour, two extensions of the basic framework are looked at, namely the existence of risk-aversion and the combination of accident-related (punitive) fines and non-accident related payments. In the context of accident law the assumption of risk-neutral drivers allows to focus on the incentives for efficient care and activity choices but to ignore the consequences of variations in payoffs across different states of nature. However, the optimality of specific liability rules may no longer hold if the party which bears the costs of an accident is not risk-neutral. This is because the payoff in the case of an accident, $G(x, z) - D(x, z)$ for driver 1 in the model of Section 3, and assuming the correct incentives for efficient behaviour, i. e. $\alpha = 1$, is significantly lower than in the absence of an accident, $G(x, z)$. Thus, the expected utility of a risk-averse driver EU = vU[G(x, z) - D(x, z)/v] + (1 - v)U[G(x, z)], where v is the probability of an accident and U the strictly concave utility function, U' > 0, U" < 0, is less than the utility of the expected payoff U[G(x, z) - D(x, z)]. If such a trade-off between efficient incentives for care and activity choices and an optimal distribution of risk occurs, in general, clear-cut statements about optimal rules will no longer be feasible (Shavell 1987). Basically, the same problem arises in the model presented here. However, it can be argued that the impact of risk-aversion is less pronounced than in the predominating models of accident law. This will be the case if fine payments are incurred sufficiently often and effectively become certain fines because drivers cannot avoid them. In such a setting, the payoff variation due to an accident for driver 1 is only αD(x, z), since (1 - α)D(x, z) = P_1(x, z) is incurred as a (quasi-) certain fine payment. Hence, the existence of non-accident related fines mitigates the payoff variation due to accidents and, therefore, weakens the conflict between efficient incentives and optimal risk allocation.

The theoretical results have generally been illustrated with reference to road traffic. A pertaining feature of road traffic is the co-existence of accident-related penalties and accident-independent fines for traffic violations. Suppose, therefore, that a driver is fined in the event of an accident and let the accident-related fine Ω depend on care and activity choices, $\Omega = \Omega(x, z)$. The fine cannot be avoided by a sufficiently high care level, but only be reduced and can include a punitive damage payment. For simplicity, a setting of unilateral decisions is analysed. Finally, let the probability of being fined in the case of an accident be q(x, z). The driver's expected payoff, given the co-existence of accident-related fines Ω and accident-independent fines $\tilde{P}$(x, z), becomes:

$$\underset{x,z}{\text{Max}}\begin{cases} G(x,z) - \alpha D(x,z) - \tilde{P}(x,z) - q(x,z)\Omega(x,z), & \text{if } x < s \\ \\ G(x,z) - \alpha D(x,z) - q(x,z)\Omega(x,z), & \text{if } x \geq s \end{cases} \qquad (7)$$

From equation (7), it is obvious that accident-related fines can be employed to induce efficient outcomes if they exactly compensate for those expected costs of an accident which are not internalised. However, given a positive probability that no fine is incurred despite an accident, because of no legal obligation to report an accident or due to hit-and-run behaviour, Ω has to be fairly high to warrant full internalisation. Whether accident-related punitive damages or non-accident-related fines are employed, may, thus, be an issue of political expediency, enforcement costs or technology. The fundamental suitability of fines $\tilde{P}$ which are unrelated to the occurrence of an accident for achieving efficiency is not altered by their co-existence with punitive damages. Given qΩ(x, z) < (1 - α)D(x, z), an expected fine $\tilde{P}(x,z)$ = (1 - α)D(x, z) - qΩ(x, z) would achieve this objective. However, such an act-based fine requires an excessive standard while harm-based payments necessitate excessive, i.e. punitive damages.

5. Discussion

The above analysis has shown that act-based sanctions can induce efficient behaviour. There are a number of advantages of act-based or non-accident related fines over other mechanisms to induce efficient behaviour especially in a world of bilateral care and activity choices. First, in comparison to harm-based, punitive sanctions, act-based fines can probably not be evaded as easily as it will be possible if fines are only imposed in the case of accidents and the incentives for hit-and-run behaviour are pronounced. Second, since high activity drivers are likely to be fined more often than low activity drivers, for a given level of care, fines for the violation of traffic rules can be made dependent on the level of activity without the need to the observe activity choices for each individual driver in the case of an accident. Third, moderate fines for the violation of traffic regulations are an established element of many legal systems, whereas 'full-cost' fines in the case of an accident are not. Thus, there are substantial arguments for a system of repeated but modest fines.

However, there are also disadvantages of a system of double strict liability. This mechanism to achieve efficiency increases the aggregate costs of an activity beyond its actual level because the full expected accident costs are imposed on all parties. If individuals compare the payoff from driving and another activity which is not burdened by the double strict liability rule, the choice between these two activities will be biased towards the second activity. Thus, although the marginal incentives may be correct, the absolute costs are inflated such that too little participation is chosen. However, this criticism applies to all systems of double strict liability. In addition, an elaborate system of monetary fines involves substantial operating costs. Finally, a system of act-based fines in a world with a variable activity level requires the willingness to model agents as not adhering to legal standards. In contrast to a setting with harm-based liability rules which individuals always adhere to, a world with fines which are independent of the occurrence of an accident can elucidate the observation that norms are violated.

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7. Appendix: Equilibrium with Bilateral Care and Activity Choices

Assume that the fine for driver 1 is $P_1(x, z) = D(x, z, y^*, u^*)(1 - \alpha)$ while that for driver 2 is given by $P_2(y, u) = D(x^*, z^*, y, u)\alpha$. Such fines induce both types of drivers to select the efficient levels of activity and care, z* and x*, and u* and y*, respectively. The proof proceeds as follows: first, it is shown that the best response by driver 1 to an efficient behaviour by driver 2 is to select the efficient care and activity levels, and that the same argument holds for driver 2. Thus, any equilibrium other than the efficient one must involve a deviation from efficient behaviour by both drivers. Subsequently, it is demonstrated that it cannot be optimal for driver 1 to select values of z and x, such that $z \neq z^*$ and/or $x \neq x^*$, if driver 2 has selected $u \neq u^*$ and/or $y \neq y^*$. However, if driver 1 selects $z = z^*$ and $x = x^*$, driver 2 will also make efficient choices, that is $u = u^*$ and $y = y^*$.

Assume that $y = y^*$ and $u = u^*$ hold. Given $P_1(x, z) = D(x, z, y^*, u^*)(1 - \alpha)$, the maximisation of drivers 1's objective W_1 is then equivalent to the maximisation of W (cf. equations (1) and (2)). Thus, if driver 2 selects the efficient care and activity levels, so will driver 1 do. An analogous argument for driver 2 shows that $P_2(y, u) = D(x^*, z^*, y, u)\alpha$ will ensure $u = u^*$ and $y = y^*$ if driver 1 has chosen $z = z^*$ and $x = x^*$.

Thus, another equilibrium than the efficient one will only exist if both drivers deviate from the optimal outcome. The payoff from deviation for driver 1 [2] for an arbitrary value of α, given a non-efficient behaviour by driver 2 [1], is denoted $W_1 = W_1(\alpha, z, x)$ [$W_2 = W_2(\alpha, y, u)$]:

$$W_1(\alpha, z, x) \equiv G(x, z) - \alpha D(x, z, y, u) - (1 - \alpha)D(x, z, y^*, u^*) \tag{A.1}$$

$$W_2(\alpha, y, u) \equiv \Gamma(y, u) - (1 - \alpha)D(x, z, y, u) - \alpha D(x^*, z^*, y, u) \tag{A.2}$$

The payoff for driver 1 from selecting the efficient levels of care and activity, given non-efficient behaviour by driver 2, is denoted by $W_1^* = W_1^*(\alpha, z^*, x^*)$. The payoff for driver 2 is defined accordingly. It will be profitable for driver 1 not to choose care and/or activity levels efficiently if $W_1 > W_1^*$ holds. This implies:

$$\begin{aligned} W_1 &\equiv G(x, z) - \alpha D(x, z, y, u) - (1 - \alpha)D(x, z, y^*, u^*) \\ &> G(x^*, z^*) - \alpha D(x^*, z^*, y, u) - (1 - \alpha)D(x^*, z^*, y^*, u^*) \equiv W_1^* \end{aligned} \tag{A.3}$$

An according computation for a driver 2 yields as a condition for not making the efficient choices:

$$\begin{aligned} W_2 &\equiv \Gamma(y, u) - (1 - \alpha)D(x, z, y, u) - \alpha D(x^*, z^*, y, u) \\ &> \Gamma(y^*, u^*) - (1 - \alpha)D(x, z, y^*, u^*) - \alpha D(x^*, z^*, y^*, u^*) \equiv W_2^* \end{aligned} \tag{A.4}$$

Since non-efficient levels of care and activity will only be chosen if both drivers deviate, the inequalities captured by (A.3) and (A.4) must both hold simultaneously. Thus, a necessary requirement for deviation to be an equilibrium is $W_1 + W_2 > W_1^* + W_2^*$. However, this requirement contradicts the assumption that x*, z*, y*, and u* uniquely maximise W, since:

$$\begin{aligned} W_1 + W_2 &= G(x, z) - D(x, z, y, u) - (1 - \alpha)D(x, z, y^*, u^*) + \Gamma(y, u) - \alpha D(x^*, z^*, y, u) \\ &= W(x, z, y, u) - (1 - \alpha)D(x, z, y^*, u^*) - \alpha D(x^*, z^*, y, u) \\ &< W(x^*, z^*, y^*, u^*) - (1 - \alpha)D(x, z, y^*, u^*) - \alpha D(x^*, z^*, y, u) \\ &= G(x^*, z^*) - \alpha D(x^*, z^*, y, u) - D(x^*, z^*, y^*, u^*) + \Gamma(y^*, u^*) - (1 - \alpha)D(x, z, y^*, u^*) \\ &= W_1^* + W_2^* \end{aligned} \tag{A.5}$$