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Individual or Enterprise Liability? The Roles of Sanctions and Liability Under Contractible and Non-contractible Safety Efforts

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Abstract: This paper analyzes the social effectiveness of fines (sanctions) and awards (liability) where accident risks are influenced by decisions made by both the enterprise and the employees of the enterprise (individuals). The regulator observes a proportion of accidents and the safety decision of the individual can be contractible or non-contractible for the enterprise. All sanction regimes yield the first best, given contractible individual care. The liability regimes, however, produce sub-optimal solutions. Given non-contractible individual care, the combined use of an individual sanction and an enterprise sanction (joint use) produces the first best. The exclusive use of an individual sanction produces the first best if the enterprise does not suffer any direct harm. The exclusive use of an enterprise sanction does not, however, produce the first best. If both decision-makers are solvent and have similar liability probabilities, then individual and enterprise liability do equally well under contractible individual care. Individual liability does, however, best for non-contractible individual care.

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JEL Classifications: D62, D82, K20, K32, I18, L51

1 Introduction

In the literature there is a debate on medical malpractice and the relative attractiveness of individual and enterprise (firm or corporate) liability.[1] Critics

1 According to McLean (2002) it is common to define enterprise liability as a method for shifting liability for adverse events that occur during the delivery of health care from the individual physician to the business organization that provided the medical care.

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of medical malpractice advocate shifting liability from physicians to the organizations that deliver health care:

> *The hospital consequently is best placed to make decisions about how to assure medical quality and prevent medical injury"* (Abraham and Weiler, 1994:32). *"Tort law would exert a more effective preventive influence against future medical injuries because the focus of liability would be at the level of the institution whose memory, planning, and decision-making is most susceptible to legal/financial incentives"* (Abraham et al., 1993:356). *"The argument is that the organizational unit ultimately responsible for the delivery of efficient health care should also bear the direct financial liability to achieve the full internalization of the costs associated with patient harm"* (Sage et al., 1994:7). *"Hospital enterprise liability would revive the deterrent power of medical malpractice law.* (Peter, 2008:370)

The intention of this paper is to analyze the preventive role of individual and enterprise liability using an analytical model that includes important characteristics of enterprises that operate risky activities. Managers and employees in many sectors, such as health care, transport, environmental pollution and occupational safety, play important roles in the prevention of accidents. Management typically invests in routines, guidelines, and safety equipment and employees use these systems when making safety decisions. A regulator may, in situations such as this, need to steer the safety decisions of both the management and employees. Additionally, accidents can inflict harm on both decision-makers and third parties (stochastic externalities). There are also contractual relationships between management and employees. Management is therefore normally in a better position than the regulator to steer the decentralized decisions of its employees.

We study an employer (enterprise) and an employee (an individual) and their influence on accident probability (multiple injurers). The model contains four externalities; two third party externalities (one generated by the enterprise and one by the individual) and two mutual ones (between the enterprise and the individual). Safety decisions are unobservable by the regulator. The regulator, however, observes a proportion of accidents. The individual observes the safety efforts of the enterprise while the enterprise may or may not be able to contract with the individual. Non-contractible individual safety effort implies that it is prohibitively expensive for the enterprise to specify efforts in a way that can be verified by a court ex post (Grossmann and Hart, 1986; Hart, 1995; Broussau and Glachant, 2002).

The regulator may use fines (sanctions) or damages (liability). Both are perceived as being transfers of wealth without any resource implications. The difference between sanction regimes and liability regimes is that sanction regimes do not allow for penalty multipliers, because damages are set equal to third-party harm.[2] The liability regime is one of strict liability. We do not consider the possibility of court errors and situations in which safety efforts impact the expected magnitude of harm.

Our model relates to the literature on; (*i*) multiple tortfeasors, and (*ii*) extended liability (delegated control).[3] The literature on multiple tortfeasors are typically assuming injurers that are independent entities (non-contractual relationships) (see e. g. Landes and Posner, 1980; Kornhauser and Revesz, 1989, 1990; Young et al., 2007). In our work there is, however, a contractual relationship between the injurers. Contractual relationships are assumed in works on extended liability. This literature does not, however, portray the principal as an injurer.

The literature on extended liability identifies the conditions in which a shift of liability from an agent to the principal is desirable (vicarious liability) (see e. g. Newman and Wright, 1990; Polinsky and Shavell, 1993; Chu and Qian, 1995; Shavell, 1997).[4] According to Dari-Mattiaci and Parisi (2004), the two main reasons in support of vicarious liability are; (*i*) the agent is insolvent while the principal is solvent (avoid judgment-proofness),[5] and (*ii*) multiple agents makes it more effective to hold the principal liable (avoid disappearing defendants).[6] Subsequent work such as that of Landeo et al. (2007), Bisso and Choi (2008), and Boyer and Porrini (2011) discuss the role of court errors in the design of incentive contracts and the distribution of liability. This literature can be subdivided into two categories; (*i*) cases in which the principal and the agent are parties to a contract which explicitly specifies the level of precaution that the agent shall take, and (*ii*) cases in which the contract fails to specify the level of precaution (Dari-Mattiaci and Parisi, 2004).[7]

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2 Damages, compensation and awards are frequently used to refer to the amount a liable party has to pay.

3 Some of the literature on the joint use of ex-post and ex-ante regulation is related to our study. See e. g. Shavell (1984), Kolstad et al. (1990), Schmitz (2000), De Geest and Dari-Mattiaci (2007), Bhole and Wagner (2008).

4 Early contributions clarified the logic of extended liability and the extent of their application (Sykes, 1981; Kornhauser, 1982). Newman and Wright (1990) proved that, under a strict liability rule, the socially optimal level of care can be achieved if the principal faces vicarious liability. Chu and Qian (1995) discuss the effect of vicarious liability under a negligence rule when the principal holds the evidence for their agent's liability.

5 The judgment-proofness problem describes a situation in which an economic agent may not have verifiable resources to pay for damages, which implies that injurers have a positive probability of escaping law suits.

6 This problem refers to the difficulty in identifying which of the agents caused the accident.

7 For a somewhat different approach see Dari-Mattiaci and Parisi (2004). Here various regimes of vicarious and secondary liability, where the principal's delegation of control over the agents incurs monitoring costs, are analyzed.

An important feature of our model is an enterprise that provides care that affects the likelihood of an accident. Furthermore, the enterprise is in a contractual relationship with another injurer (the individual).[8] Four findings derive from our analysis. Firstly, the first best can be achieved by imposing sanctions exclusively on the enterprise and exclusively on the individual given that the enterprise is contractually able to specify a care level for the individual. Secondly, when the enterprise cannot specify a care level for the individual, the first best solution can be achieved only if imposing both sanctions (joint use). This sanction regime involves an accident subsidy on the enterprise. Thirdly, when the enterprise cannot specify a care level for the individual, the targeting of the individual does better in welfare terms than the targeting of the enterprise. This finding follows because the enterprise internalizes the effect on the individual (via the participation constraint) while the individual does not internalize the effect on the enterprise. Fourthly, we find, for similar liability probabilities, that the two types of liability (individual and enterprise liability) can do equally well. This occurs when the enterprise can specify the individual's level of care. Individual liability does better when this is not possible.

The remainder of this paper is structured as follows. Section 2 develops the model and presents the first best. Section 3 derives optimal sanctions where individual care is non-contractible and Section 4 derives optimal sanctions where individual care is contractible. Section 5 analyses and compares individual and enterprise liability for contractible and non-contractible individual care and Section 6 concludes and discusses our findings.

2 The model and the first best solution

Consider a model that is comprised of the management of a firm, an employee of the firm (the individual), and a regulator. Both the firm and the individual can influence the probability of an accident. Accident probability, $P(E,e)$, is therefore a function of the firm's safety efforts (E) and the individual's safety efforts (e). We make the following assumptions:

$$P'_E(E,e) < 0, \quad P'_e(E,e) < 0, \quad P''_{EE}(E,e) > 0, \quad \textit{and} \quad P''_{ee}(E,e) > 0, \tag{1}$$

8 There is also literature that considers probability-reducing care and loss-reducing care (Dari-Mattiaci and De Geest, 2005; De Geest and Dari-Mattiaci, 2007).

$$\lim_{E\to 0} P'_E(E,e) \to \infty;\ \lim_{E\to\infty} P'_E(E,e) \to 0;\ \lim_{e\to 0} P'_e(E,e) \to \infty; \quad and \quad \lim_{e\to\infty} P'_e(E,e) \to 0, \tag{2}$$

$$P''_{EE}(E,e)P''_{ee}(E,e) - P''_{Ee}(E,e)P''_{eE}(E,e) > 0. \tag{3}$$

The above assumptions relate to accident technology; assumption 1 implies that the accident technology is strictly negative and strictly convex in safety efforts, assumption 3 implies that the same technology is concave in (E, e), while assumption 2 ensures interior solutions to subsequent optimization problems.[9] The cross partial derivative of the accident probability function can be positive, negative, or zero. $P''_{eE}(E,e) = P''_{Ee}(E,e) > 0$ implies that more preventive individual effort is less effective in reducing the accident probability, the higher the preventive effort of the firm. It is also assumed that the expected social cost associated with an accident (D) is the sum of accident costs to the firm (βD), individual accident costs (αD), and the accident costs inflicted upon a third party (γD), where β, α and γ are shares that total to one.[10] The marginal safety effort costs of the firm (K) and the individual (k) are strictly positive. The last two assumptions (assumption 4 and 5) can be formulated as;

$$\beta \geq 0, \alpha > 0, \gamma \geq 0 \ \ and \ \ \beta + \alpha + \gamma = 1 \tag{4}$$

$$k > 0 \text{ and } K > 0 \tag{5}$$

The individual earns the expected reservation utility, $\bar{U}$, where the expected utility, U, is the wage income $I(e)$, less the sum of the expected individual accident costs, $P(E,e)\alpha D$, expected individual sanction costs, $P(E,e)st$, and individual care costs, ke.[11] Individual sanction costs are the product of the accident probability, the fine (t), and the probability of being sanctioned in

9 Derivates are denoted in the following way; $\partial P(E,e)/\partial E \equiv P'_E(E,e)$ and $\partial^2 P(E,e)/\partial E^2 \equiv P''_{EE}(E,e)$.

10 In a patient safety setting, an accident is the occurrence of a medical error, where αD is physician costs such as time costs, emotional distress, and reputation costs, βD is hospital costs such as reputation costs and treatment costs associated with complications arising from medical errors, and γD is patient costs due to prolonged treatment and impaired health and human sufferings.

11 In what follows we, for simplicity, refer to expected accident costs and expected sanction costs as accident costs and sanction costs, respectively. We also use the concepts of fines and sanctions interchangeably.

the event of an accident, s, where $0 < s \le 1$.[12] Two types of internal contracts are considered. Firstly, we consider the situation in which individual effort is non-contractible. A fixed wage contract is, therefore, introduced. Secondly, we consider the situation where individual effort is contractible, meaning that a contract between the firm and the individual, which is contingent upon effort, is enforced. In this case a linear incentive contract is studied. Wage income, $I(e)$, can therefore be represented by the following contract; $I(e) = A + be$, where A is a fixed wage component and b is an incentive component. The expected utility for the individual therefore is;

$$U(E,e) = A + be - P(E,e)\alpha D - P(E,e)st - ke \ge \bar{U} \tag{6}$$

According to (6), the safety effort of the firm, E, affects the expected utility of the individual via the accident probability function.

The firm's expected costs are the sum of wage expenses, $A + be$, accident costs to the firm, $P(E,e)\beta D$, the firm's safety investment costs, KE, and the firm's sanction costs, $P(E,e)rT$, where T is the sanction upon the firm and r the conviction probability where $0 < r \le 1$.

$$C(E,b) = (A + be) + P(E,e)\beta D + P(E,e)rT + KE \tag{7}$$

The regulator is concerned with expected social costs, $S(E,e)$, which is the sum of social accident costs and safety effort costs;

$$S(E,e) = P(E,e)D + KE + ke. \tag{8}$$

The regulator minimizes (8) with respect to E and e.[13] Interior solutions follow from (1)–(5), the equation system that defines the first best is;

$$-P'_e(E^{FB}, e^{FB})D = k \tag{9}$$

12 When analyzing fines, s is the probability of the individual being sanctioned and r is the probability of the firm being sanctioned. In the following we denote them as "conviction probabilities." A probability equal to one describes conviction certainty and a probability less than one describes conviction uncertainty. A strictly positive probability means that a share of all accidents is costlessly detected. In Section 5, when discussing liability, r and s become the probabilities of being sued and held liable in the event of an accident (liability probabilities).

13 In what follows we denote equilibrium values only when needed for comparisons. All second order conditions are presented in Appendix A.

$$-P_E'(E^{FB}, e^{FB})D = K \tag{10}$$

where the superscript *FB* denotes first best. It follows from (9, 10) that, for each safety variable, the expected marginal reduction in society's costs is equal to safety unit costs.

3 Optimal sanctions given non-contractible individual care

The costs to the firm for monitoring the individual's safety care are, in what follows, prohibitively high (non-contractible effort). This implies that the incentive component of the linear wage contract equals zero (fixed wage). We study a sequential game where the regulator first decides on t and T, then the firm decides on A and E, and finally the individual decides on e.[14] This is a game of three stages and five endogenous variables (t, T, E, e, A) that is solved by backward induction.

In the final stage, the individual maximizes (6) for $b=0$, with respect to e, which produces $U_e'(e, E) = -P_e'(E, e)[\alpha D + st] - k = 0$, that can again be expressed as;[15]

$$-P_e'(E, e)[\alpha D + st] = k \tag{11}$$

Equation (11) states that optimal care is determined by equalizing the marginal change in costs (the sum of accident and sanction costs) and the marginal safety effort cost. Note that the accident costs of both the firm and the third party are not internalized by the individual. Equation (12) determines the individual's response function:[16]

14 That an individual is able to observe the safety decisions of the firm seems realistic, as firms typically adopt various types of safety structures (information technology, protective equipment, detectors etc.) that are easily observable by employees. Furthermore, rules and regulations are typically announced to employees. The sequential nature of the game seems to be relevant in the light of firms making safety investments and individuals tending to make day-to-day decisions.

15 An interior solution follows from (1)–(5) and $st > -\alpha D$.

16 It follows that individual care increases with t, and increases, decreases, or is independent of E because $e_t'(E, t) = -P_e'(E, e)s/P_{ee}''(E, e)(\alpha D + st) > 0$ and $e_E'(E, t) = -P_{eE}''(E, e)/P_{ee}''(E, e) \geq (<) 0$.

$$e = e(E, t) \tag{12}$$

In stage two, the firm chooses A and E. By inserting a binding version of (6) into (7), for $b = 0$, and taking (12) into consideration, we arrive at the following minimization problem;

$$\underset{E}{Min}\ C(E) = \bar{U} + P(E, e)\Psi + ke + KE \quad s.t.\ \ e = e(E, t), \text{ where } \Psi \equiv (\alpha + \beta)D + rT + st \tag{13}$$

We observe that the firm internalizes individual accident costs (αD) and individual sanction costs (st). The participation constraint can be said to internalize the individual's costs into the firm's decision and occurs because the individual must be financially compensated by the firm for being exposed to accident and sanction costs. The first order condition then becomes;

$$C_E'(E) = \left[P_E'(E, e(E, t))\Psi + K\right] + e_E'(E, t)\left[P_e'(E, e(E, t))\Psi + k\right] \geq (<) 0. \tag{14}$$

This condition is, from (1)–(5) and $\Psi > 0$, binding. Inserting (11) and rearranging yields;

$$\begin{aligned} P_E'(E, e(E, t)) &= -\frac{1}{\Psi}\left[K + \left(1 - \frac{\Psi}{\alpha D + st}\right) ke_E'(E, e(E, t))\right] \\ &= -\frac{1}{\Psi}\left[K - \frac{(\beta D + rT)}{\alpha D + st} ke_E'(E, e(E, t))\right] < 0 \end{aligned} \tag{15}$$

Equation (15) defines the firm's response function;[17]

$$E = E(T, t) \tag{16}$$

It follows from the second term of the parenthesis in (15) that the optimal choice of E depends on the accident technology (strategic independent, strategic substitutes or strategic complements). This reflects that the firm steers, in an indirect way, the individual's choice of e through their setting of E (indirect effect). This interaction appears through the effect that the firm's safety effort has on the individual's effort and its feedback into the firm's problem. For example, if the safety efforts are strategic substitutes, $P_{ee}''(E, e) > 0 \Rightarrow e_E'(E, e) < 0$, then the firm pays attention to the discouraging effect a higher level of E has on e, as e is

17 The partial effects as concerns the firms' safety effort are given in Appendix B.

decisive for the payoff of the firm. The significance of this indirect effect depends on the size of the two sanctions and the direct harm suffered by the firm and the individual.

In the first stage, the regulator minimizes (8) by choosing t and T, taking into account the response functions (12) and (16). The optimization problem therefore becomes;

$$\underset{T,\,t}{Min} \quad S(E,e) = P(E,e)D + KE + ke \quad s.t. \;\; e = e(E(T,t),t) \; and \, E = E(T,t) \tag{17}$$

Solving the minimization problem using (11) and (15), we arrive at the following conditions;[18]

$$[1/(\alpha D + st)][st - (\gamma + \beta)D]k = 0 \quad \text{and} \quad (rT + st - \gamma D)K = -[1/(\alpha D + st)][\beta D + rT]Dk e'_E(\star) \tag{18}$$

3.1 The optimal sanctions given joint use (*JS*)

When an individual and an enterprise sanction is permitted (joint use), the sanction levels that fulfill (18) are;[19]

$$st_{FW}^{JS} = (\gamma + \beta)D \quad \text{and} \quad rT_{FW}^{JS} = -\beta D \tag{19}$$

The sanction levels in (19) produce the first best ($S_{FW}^{JS} = S^{FB}$).[20] It follows that the optimal sanctions are adjusted for the size of the conviction probabilities. The optimal individual sanction is positive and equal to the sum of firm harm and third party harm. The optimal enterprise sanction is negative and equal to the absolute value of the firm's harm. The sum of the two sanctions equals third party harm. The individual sanction induces the individual to internalize firm harm and third party harm. This sanction level, via the participation constraint, makes the firm do the same. As the firm already internalizes own harm, a subsidy equal to βD is in demand to avoid a situation in which the total harm

18 In what follows, to simplify notation, we apply (*) to denote the arguments of functions. The first order conditions for problem (17) are given in Appendix C.

19 Superscript *JS* refers to optimal joint use of sanctions. Subscript *FW* refers to non-contractible individual care.

20 This follows from inserting the two sanction levels of (19) into (11) and (15). This procedure produces the two first order conditions presented in (9, 10).

internalized by the firm exceed the social harm ("overprecaution" problem). There may be institutional barriers against subsidizing a firm in the event of an accident. If so, this sanction regime will not produce the first best. When the firm suffers no direct harm ($\beta = 0$), the first best is achieved by letting the individual sanction be equal to third party harm and the firm sanction equal to zero.

3.2 The optimal enterprise sanction (*ES; t* = 0)

The use of an exclusive enterprise sanction cannot fulfill (19). This regime therefore produces suboptimal safety levels. The optimal enterprise sanction level (*ES*) is obtained by solving the maximization problem of the regulator with respect to *T*, for $t = 0$, this yielding $\left[P_e'(\star)D + k\right]E_T'(\star)e_E'(\star) = -\left[P_E'(\star)D + K\right]E_T'(\star)$. Substituting (11) and (15) into this expression, retaining $t = 0$, and solving with respect to *rT* yields;

$$rT_{FW}^{\star ES} = \frac{K + ke_E'(\star)}{K + ke_E'(\star)}\gamma D = \gamma D \tag{20}$$

ES has the following properties; (*i*) strictly positive (not negative as under *JS*), (*ii*) independent of firm accident costs, and, (*iii*) zero in the absence of third party accident costs. Using (11) for $t = 0$ and substituting (20) into (15) yields the following two conditions for the optimal safety effort levels;

$$-P_e'(E_{FW}^{\star,\,ES}, e_{FW}^{\star,\,ES})D = \frac{k}{\alpha} \tag{21}$$

$$-P_E'(E_{FW}^{\star,\,ES}, e_{FW}^{\star,\,ES})D = K - \frac{(\beta + \gamma)}{\alpha}ke_E'(\star) \tag{22}$$

From (22) we see that optimal firm effort is a function of an indirect effect. The significance of this effect depends on $(\beta + \gamma)/\alpha$, the numerator referring to accident costs that are non-internalized by the individual and the denominator referring to the accident costs that are internalized by the individual. From (20) we observe that *ES* is independent of any indirect effect. This finding follows because the firm, as desired by the regulator, internalizes all social costs. The regulator therefore accepts the firm's steering of individual safety care.

3.3 The optimal individual sanction (*IS; T* = 0)

The exclusive use of an individual sanction cannot fulfill (19). This regime therefore produces suboptimal safety levels.[21] The optimal individual sanction level (*IS*) is derived by solving the maximization problem of the regulator with respect to t, for $T=0$. This yields; $P_E'(\star)D+K=-\left[P_e'(\star)D+k\right]\Phi$ where $\Phi\equiv\left[e_E'(\star)E_t'(\star)+e_t'(\star)\right](1/E_t'(\star))$. Substituting (11) and (15) and retaining $T=0$ yields;

$$\left[\frac{st_{FW}^{IS}-\gamma D}{st_{FW}^{IS}+(1-\gamma)D}\right]K = -\left[\left(\frac{st_{FW}^{IS}-(\beta+\gamma)D}{st_{FW}^{IS}+(1-\beta-\gamma)D}\right)\Phi+\frac{\beta D^2}{[st_{FW}^{IS}+(1-\beta-\gamma)D][st_{FW}^{IS}+(1-\gamma)D]}e_{E(\star)}'\right]k \tag{23}$$

We observe that for $\gamma=\beta=0$ (the firm and the third party suffer no harm), (23) is fulfilled for $st_{FW}^{IS}=0$. This is as expected, as all externalities are absent. To simplify (23), assume that $\gamma>0$ and $\beta=0,$ which implies that (23) becomes;

$$\left[\frac{st_{FW}^{IS}-\gamma D}{st_{FW}^{IS}+(1-\gamma)D}\right]K=-\left[\left(\frac{st_{FW}^{IS}-\gamma D}{st_{FW}^{IS}+(1-\gamma)D}\right)\Phi\right]k \tag{24}$$

It is now straightforward to see that (24) is fulfilled for $st_{FW}^{IS}=\gamma D$. Assuming that $\gamma=0$ and $\beta>0,$ implies that (23) can be expressed as;

$$\left[\frac{st_{FW}^{IS}}{st_{FW}^{IS}+D}\right]K=-\left[\left(\frac{st_{FW}^{IS}-\beta D}{st_{FW}^{IS}+(1-\beta)D}\right)\frac{e_t'(\star)}{E_t'(\star)}+\left(\frac{st_{FW}^{IS}(st_{FW}^{IS}+(1-\beta)D)}{[st_{FW}^{IS}+(1-\beta)D][st_{FW}^{IS}+D]}\right)e_{E(\star)}'\right]k \tag{25}$$

Inserting $st_{FW}^{IS}=\beta D$ into (25) confirms that this specific sanction level does not satisfy this condition. The firm now internalizes own accident costs through the individual sanction, despite these costs already being internalized by the firm. This means there is an "overprecaution" problem. From the last term of (25), we observe that *IS* depends on the sign of an indirect effect. Assuming $P_{eE}''=0\Rightarrow e_E'=0,$ allows this term to be ignored and we get; $st_{FW}^{IS}<\beta D$ for $E_t'>0$ and $st_{FW}^{IS}>\beta D$ for $E_t'<0.$[22] The same conclusions are valid for $P_{eE}''>0\Rightarrow e_E'<0.$

21 An exception occurs if the firm suffers no direct harm; $\beta=0$.

22 The expressions for the partial derivatives are given in Appendix B.

Given $P''_{eE} < 0 \Rightarrow e'_E > 0$, we cannot rule out that $st^{IS}_{FW} > \beta D$ for $E'_t < 0$. Finally, consider the general case where $\gamma > 0$ and $\beta > 0$ (see 23). It follows that $st^{IS}_{FW} < (\beta + \gamma)D$ for $e'_E \geq 0$ and $E'_t > 0$, while $st^{IS}_{FW} > (\beta + \gamma)D$ for $e'_E \leq 0$ and $E'_t < 0$.

3.4 Comparing *IS* and *ES*

We know from the above that *ES* does not achieve the first best. *IS*, however, achieves the first best if firm accident costs are zero ($\gamma > 0$ and $\beta = 0$). *IS* therefore does better than *ES* in this particular case (see 20). Including firm accident costs leads, however, to a complex expression (see 23) that makes a comparison with *ES* challenging. We therefore consider a number of specific cases below. Firstly, we consider the case of absent third party costs ($\gamma = 0$ and $\beta > 0$). From (20) and (25) we observe that; (*i*) neither regime produces the first best, (*ii*) *ES* is zero ($rT^{ES}_{FW} = 0$), and (*iii*) *IS* is strictly positive ($rt^{ES}_{FW} > 0$). Secondly, let each of the two sanctions be equal to zero (no regulation). If so, the social cost is the same in the two regimes. From this it follows that a strictly positive *IS* outperforms *ES* for $\gamma = \beta > 0$. Thirdly, assume that $\gamma > 0$ and $\beta > 0$ combined with each sanction being equal to third party harm ($st = rT = \gamma D$). From (20) it follows that an enterprise sanction equal to γD is optimal (equal to *ES*). From (23) it follows that an individual sanction equal to γD is suboptimal (deviates from *IS*). The individual sanction regime ($st = \gamma D$), will, however, ceteris paribus, outperform the enterprise sanction regime ($rT = \gamma D$). This conclusion follows as the firm internalizes own harm and third party harm for each of the two sanction regimes. The individual internalizes own harm and third party harm given the individual sanction regime. However, only own harm is internalized by the individual given the enterprise sanction regime. This makes it clear how an individual sanction encourages both decision-makers to internalize third party harm. An enterprise sanction, however, only encourages the firm to internalize third party harm. The ability to steer the individual might, furthermore, be of greater importance than steering the firm, as the individual internalizes a lower share of the social accident cost than the firm in the absence of any sanctions.[23,24]

23 The individual internalizes own accident costs, while the enterprise internalizes own and individual accident costs. This is seen by comparing the first order condition of the individual for the two sanction regimes; $-P'_e(E,e)D = k/\alpha$ (enterprise sanction regime) and $-P'_e(E,e)D = k/\left(\alpha + st^{IL}_{FW}\right)$ (individual sanction regime).

24 This argument, however, builds upon the assumption that individual safety care is not much less productive than the firms' safety care.

The ability of *IS* to outperform *ES* rests on the assumption that the firm is unable to induce the individual to internalize own costs.[25] In reality, however, firms can apply other measures than wage contracts to make the individual, at least to some extent, care about the firm. One example is non-financial incentives such as administrative and management strategies and normative influences such as creating a professional culture. Shavell (1993) studied firms with a limited ability to impose financial penalties on employees and describe how the threat of job-loss combined with supernormal wages (above market wage) may act as a superior incentive mechanism. This finding directs our attention to the possibility of using ex-post events as part of the firm's internal control environment. We have so far assumed that the occurrence of accidents is non-contractible for the firm and contractible for the regulator. However, it seems reasonable that a situation in which accidents are contractible for the regulator they will also be contractible for the firm. If so, a firm sanction, *f*, applies, that is contingent upon $zP(E, e)$, where z is the probability of the individual being sanctioned by the firm. The optimal internal sanction and the optimal regulator sanctions are presented in Appendix D. It follows from this that the optimal internal sanction for *ES* is $z\bar{f}^{ES} = \beta D + r\bar{T}$ and the optimal enterprise sanction becomes $r\bar{T}^{ES} = \gamma D$, thus $z\bar{f}^{ES} = (\beta + \gamma)D$. The optimal internal sanction for *IS* becomes $z\bar{f}^{IS} = \beta D$ and the optimal individual sanction becomes $s\bar{t}^{IS} = \gamma D$. From this follows that the optimal internal sanction is higher for *ES* than for *IS*. However, the sum of the incentives directed at the individual is the same for the two cases. For *IS*, the individual is confronted with sanctions issued by both the firm, $z\bar{f}^{IS} = \beta D$, and the regulator; $s\bar{t}^{IS} = \gamma D$.[26]

Both the *EL* and *IL* regulatory regimes, in the presence of an internal contract, produce the first best. This means that the regulator becomes indifferent between these two regimes and the joint use regime presented in Section 3.1. The regime presented in Section 3.1 might, however, in the presence of "accident contract costs" (costs from writing, monitoring and enforcing contracts being contingent upon accidents) be preferred by the firm. If so, the presence of "accident-contract costs" induces the firm to abstain from introducing a contract that is contingent upon accidents. This leaves the (costly) task of disciplining the individual to the regulator.[27] In this perspective, the Section 3.1 model describes

25 An explanation lying outside of our model is infinite individual risk aversion, which again implies that agents do not respond to monetary incentives (Aghion and Tirole, 1997).

26 See Appendix D for further details on the optimal internal sanctions.

27 Section 3.1 discusses the possibility of barriers against subsidizing a firm in the event of accidents. Given the existence of such a barrier, we arrive at the following sanction regime $st_{FW}^{JS} = (\gamma + \beta)D$ and $rT_{FW}^{JS} \equiv 0$, or, alternatively *IS* (see Section 3.3). In either case, we cannot rule a situation in which the occurrences of accidents are contractible, but costly, for the firm.

The resistance of organized groups to institute sanctions at decentralized levels of an organization (e. g. trade unions) is another explanation of why firms do not always use ex-post events. If this is the case, then the issuing of fines by the firm will be disputed and so generate conflict costs that may discourage the use of the same incentives.[28] The role of the firm as an injurer and at the same time issuer of sanctions is another source of disputes.[29] There are also institutions that restrict actions which can be taken. The relationships between regulators (supervision and oversight agencies), firms, and employees are typically regulated by laws, regulations and agreements. Examples include collective labor agreements (between employer associations and trade unions) and labor laws that define rights and responsibilities. Such institutions may represent institutional barriers to the use of accident occurrences as a disciplining device for firms.[30]

4 Optimal fines (sanctions) given contractible individual care

Now we study optimal fines for contractible individual care (a performance pay contract). The sequential game has three stages and six endogenous variables (t, T, b, E, A, and e). The regulator first decides on t and T, then the firm decides on A, b, and E, and finally the individual decides on e. The first order condition of the individual becomes;

$$-P_e'(E,e)[\alpha D+st]=k-b \tag{26}$$

which again defines the following individual response function;

out that the firm, also if "accident contract costs" are zero, abstains from disciplining own employees by the use of a fine in the event of accidents.

28 Firms issuing sanctions may inform regulators about the occurrence of accidents that otherwise would have remained unknown, thus increasing the risk of being sanctioned.

29 It may be difficult for firms to impose sanctions when the accident probability is a function of decisions made by both the firm and the individual, so creating uncertainty about the extent of each injurer's responsibility.

30 For example, there may be caps on sanctions issued by firms. In some cases, the two "regulatory regimes" are coordinated in the sense that "double penalties" are not allowed (simultaneous use of firm and regulator sanctions).

$$e = e(E, b, t) \tag{27}$$

The problem of the firm becomes;[31]

$$\begin{aligned} &\underset{E,b}{Min}\, C(E, b, e) = \bar{U} + P(E, e)\Psi + ke + KE \quad s.t.\ e = e(E, b, t) \\ &\text{where} \quad \Psi \equiv (\alpha + \beta)D + rT + st. \end{aligned} \tag{28}$$

The first order conditions, given interior solutions, become;

$$P_e'(E, e(E, b, t)) = -\frac{k}{\Psi} \tag{29}$$

$$P_E'(E, e(E, b, t)) = -\frac{K}{\Psi} \tag{30}$$

An expression for the optimal incentive component follows by combining (26) and (29) and solving for b, which yields;[32]

$$b(t, T) = \frac{\beta D + rT}{\Psi} k = \left[1 - \frac{(\alpha D + st)}{\Psi}\right] k \tag{31}$$

From (31) we observe that the use of performance pay is optimal also for $\beta = 0$. Furthermore, from (30) we observe that the firm's optimal effort level is independent of an indirect effect. This finding follows because, under contractible individual effort, the firm is able to steer individual effort in the desired direction via performance pay. In this perspective, the indirect effect identified for a fixed wage contract can be understood to be an imperfect substitute to performance pay (see Section 3). Equations (29–30) define the firm's response function;

$$E = E(T, t) \tag{32}$$

The problem of the regulator is;

31 The first order conditions are available from Appendix E.

32 $b_t' = -[s(\beta D + rT)](1/\Psi^2)k < 0$ and $b_T' = [r(\alpha D + st)](1/\Psi^2)k > 0$.

$$\underset{T,t}{Min}\, S(E,e) = P(E,e)D + KE + ke \text{ s.t } e = e(E,b,t) \text{ and } E = E(T,t)$$
$$\text{where } b(T,t) = [1 - (\alpha D + st)(1/\Psi)]k \quad (33)$$

The solution to the problem defined by (33) becomes;[33]

$$(1/\psi)(st + rT - \gamma D) = 0 \quad (34)$$

Intuition for (34) is provided by comparing the problem of the regulator (see 33) with the problem of the firm (see 28).[34] From this follows that the regulator aligns the incentives by setting Ψ in (28) equal to D, which again implies that $D = (\alpha + \beta)D + rT + st \Rightarrow rT + st = \gamma D$.

4.1 Optimal sanctions given joint use (*JS*)

The sanction levels that fulfill (34), where both an individual and an enterprise sanction are permitted (joint use), become;[35]

$$st_{PP}^{JS} + rT_{PP}^{JS} = \gamma D \quad (35)$$

All combinations of levels that fulfill (35) yield the first best ($S_{PP}^{JA} = S^{FB}$). It follows that in the absence of third party harm, no regulatory intervention is needed. The optimal sanction levels do not, as for a fixed wage contract, depend on firm harm. The sum of both sanctions is, however, still equal to third party harm. The sanction regime described in (35) is more flexible than the sanction regime for a fixed wage contract e. g. the optimal enterprise sanction does not need to be strictly negative.

4.2 Optimal enterprise sanction (*ES; t* = 0) and optimal individual sanction (*IS; T* = 0)

The exclusive use of an enterprise sanction and the exclusive use of an individual sanction fulfills (34). Both sanction regimes therefore produce the first best.

33 The first order conditions are available from Appendix E.

34 This means that, in the case of contractible individual care, the relationship between the firm and the individual reduces to a problem that is only concerned with the internal transfer mechanism.

35 Superscript *JS* refers to the joint use of sanctions and subscript *PP* refers to a performance pay contract.

The optimal sanction in each regime is equal to third party harm; $rT_{PP}^{ES}=\gamma D$ or $st_{PP}^{IS}=\gamma D$. The difference between these two regimes becomes evident when comparing the optimal internal contracts, $b^{ES}=[(\beta+\gamma)/(\alpha+\beta+\gamma)]k=(\beta+\gamma)k>b^{IS}=[\beta/(\alpha+\beta+\gamma)]k=\beta k$. The firm chooses a more high-powered contract under *ES* than under *IS*. Under *ES*, the firm induces the individual, via performance pay, to internalize both firm harm and third party harm. Under *IS*, the firm induces the individual to internalize firm harm.

5 Enterprise liability versus individual liability

We now extend our analysis by considering strict liability.[36] To do this, we need to define what particular harm strict liability is to address. First, we focus at the situation where damages are set equal to third party harm. For individual liability (*IL*) this implies that: *(A)* $T^{IL}=0$ and $t^{IL}=\gamma D$.[37] For enterprise liability (*EL*) this implies that: (*B*) $T^{EL}=\gamma D$ and $t^{EL}=0$.

We start out by considering contractible individual care.[38] By imposing assumptions *A* onto (23–25), (29), and (30), we arrive at the following first order conditions for individual liability (*IL);*

$$-P_e'(E_{PP}^{IL},e_{PP}^{IL})D=\frac{k}{(\alpha+\beta+s\gamma)} \tag{36}$$

$$-P_E'(E_{PP}^{IL},e_{PP}^{IL})D=\frac{K}{(\alpha+\beta+s\gamma)} \tag{37}$$

By imposing assumptions *B* onto (23–25), (29), and (30), we arrive at the following first order conditions for enterprise liability (*EL);*

36 For some conditions, an accident probability function can be used to study the negligence rule. This is the case if the due care standard is imperfectly observable due to informational limitations, inadvertent actions or court errors. If so, the risk of being held negligent becomes strictly positive also for high precautionary care levels. A problem with such an approach is that the accident probability function becomes the probability of being sued and held liable for negligence, thus first best effort cannot be determined. It is also a question as to which party any due care standard is to be applied.

37 This assumption means that we do not allow for penalty multipliers.

38 A complete model of liability would consider distributive issues (victims) and liability insurances. However, our attention is restricted to the issue of deterrence.

$$-P_e'(E_{PP}^{EL}, e_{PP}^{EL})D = \frac{k}{(\alpha+\beta+r\gamma)} \tag{38}$$

$$-P_E'(E_{PP}^{EL}, e_{PP}^{EL})D = \frac{K}{(\alpha+\beta+r\gamma)} \tag{39}$$

First consider the case in which the liability probabilities are the same for the firm and the individual $(s=r)$. For liability certainty $(s=r=1)$ both regimes achieve the first best. The two regimes are therefore equally attractive in welfare terms. Neither regime, however, achieves the first best for liability uncertainty $(s=r<1)$. This finding is the result of the inflexibility that follows from not allowing for penalty multipliers. This is a type of inefficiency that is well known from the literature (see e. g. Shavell, 1984; Schmitz, 2000). Another observation is that the social attractiveness of *EL* and *IL* is the same for $s=r<1$. If the liability probabilities differ, $s\neq r$, *EL* does better than *IL* for $r>s$, and *IL* does better than *EL* for $r<s$.

Consider now non-contractible individual care. The first order conditions for *IL* follow from imposing assumptions *A* onto (11) and (15);

$$-P_e'(E_{FW}^{IL}, e_{FW}^{IL})D = \frac{k}{\alpha+s\gamma} \tag{40}$$

$$-P_E'(E_{FW}^{IL}, e_{FW}^{IL})D = \frac{1}{(\alpha+\beta+s\gamma)}\left[K - \frac{\beta}{\alpha+s\gamma}ke_E'(*)\right] \tag{41}$$

The first-order conditions for *EL* follow from imposing assumptions *B* onto (11) and (15);

$$-P_e'(E_{FW}^{EL}, e_{FW}^{EL})D = \frac{k}{\alpha} \tag{42}$$

$$-P_E'(E_{FW}^{EL}, e_{FW}^{EL})D = \frac{1}{(\alpha+\beta+r\gamma)}\left[K - \frac{\beta+r\gamma}{\alpha}ke_E'(*)\right] \tag{43}$$

Given liability certainty $(s=r=1)$, the first best is unattainable both for *IL* and *EL*. The only exception is where the firm suffers no direct harm $(\beta=0)$. In this case the first best is only achieved for *IL*. Given liability uncertainty $(s=r<1)$, the first best is unattainable for both regimes. However, *IL* will always do better than

EL. This means that the social attractiveness of *EL* and *IL* differs for similar liability probabilities $(s = r < 1)$. This finding follows because the individual internalizes a higher share of the accident externalities under *IL* than under *EL* (see 40 and 42). If the liability probabilities differ, $s \neq r$, *IL* always does better than *EL* for $s \geq r$. For $s < r$, it cannot be ruled out that *EL* will do better than *IL*.[39,40]

The problem of judgment-proofness can also be discussed within our model framework. This is achieved, given liability certainty, by allowing the values of the parameters r and s to reflect the degree of solvency. It is now assumed that the firm is solvent while the individual is insolvent. The wealth of the firm, W, as it is solvent, must be equal to or higher than the damages; $W \geq T = \gamma D$. The solvency of the firm is then described by $r = 1$. Let s measure the ratio between the wealth of the individual, w, and damages. As the individual is insolvent, $w < t = \gamma D$, we get $s = w/\gamma D < 1$. In total, our assumptions produce the following ranking; $r = 1 > s$. We know from the discussion above that for $r > s$; (*i*) *EL* does better than *IL* if the firm can specify a care level for the individual (contractible individual care), and, *(ii) IL* may do better or worse than *EL* if the firm is unable to specify a care level for the individual (non-contractible individual care).

Finally, we briefly comment on the case in which damages are set equal to social harm. *EL* in this case implies that $T^{EL} = D$ and $t^{EL} = 0$ while *IL* implies that $T^{IL} = 0$ and $t^{IL} = D$. This version of strict liability is represented by the conditions presented above (see 36–43) for $\gamma = 1$. Compared to the case in which damages were set equal to third party harm, the conclusions now change. Suboptimal solutions follow both for liability certainty and liability uncertainty (for both contract types). The only exception is for performance pay under liability uncertainty where $\alpha + \beta = r = s < 1$.[41]

6 Conclusions

We studied a single firm in which the employer and the employee (individual) influence the accident probability (multiple injurers) and where accidents cause

39 This is seen by inserting $s = 0$ and $r = 1$ into (40, 41) and (42, 43) for $e_E'(*) = 0$. It follows that (40) and (42) coincide, (41) becomes $-P_E'(E_{FW}^{IL}, e_{FW}^{IL})D = [1/(\alpha + \beta)]K$, and (43) becomes $-P_E'(E_{FW}^{EL}, e_{FW}^{EL})D = K$. Thus *EL* now outperforms *IL* in welfare terms.

40 Comparing the firm's first order conditions for *IL* (37 and 39) and *EL* (41 and 43) makes evident that the indirect effect is present only for non-contractible individual care.

41 Other versions of the strict liability that could be applied are; (i) individual damages set equal to the sum of firm and third-party harm (individual liability), and, (ii) enterprise damages set equal to the sum of individual and third-party harm (enterprise liability).

harm to the two injurers and to a third party. The model contains four stochastic externalities; two third party externalities (one generated by the firm and one by the individual) and two mutual ones (between the firm and the individual). The safety decisions of the firm and the individual are unobservable for the regulator while a proportion of the accidents are observable. The individual can observe the safety investments of the firm and the firm may or may not be able to contract on individual safety care. For non-contractible individual effort, the two parties enter into a fixed wage contract. For contractible individual effort, a performance pay contract is in place. The participation constraint of the individual ensures that the firm internalizes the risks of the individual.

We find, when the safety decision of the individual is contractible (incentive contract), that all sanction regimes (joint use, individual sanction, firm sanction) achieve the first best and the optimal sanction (or sum of the optimal sanctions) equals third party accident costs. This conclusion follows since the mutual externalities are internalized in the absence of regulation, one via the individuals' participation constraint and one via the incentive contract. The regulator therefore needs to set sanctions equal to third party harm to achieve a full internalization. Where the safety decision of the individual is non-contractible, the regulator must make; (*i*) the firm internalize third party harm, and, (*ii*) the individual internalize third party harm and firm harm. The optimal sanctions and the implications for social welfare differ across the three sanction regimes given individual effort being non-contractible. In the joint use regime, optimal regulation consists of an individual sanction that is equal to third party harm and a strictly negative enterprise sanction (subsidy). This regime achieves the first best. In the individual sanction regime, the optimal sanction equals third party harm plus a term that reflects considerations (trade-offs) that follow from the presence of firm harm. This regime does not achieve the first best. In the enterprise sanction regime, the optimal sanction equals third party harm, and this regime does not produce the first best.

For the case of contractible individual care, the firm is able to steer the behavior of the individual in an effective way. This ultimately leads to a situation of only one decision-maker, as the firm now in principle controls both safety decisions. The regulator therefore achieves the first best by inducing the "single" decision-maker to internalize third party harm. For non-contractible individual care the regulator is confronted with a more complex situation, particularly where the firm is exposed to accident costs. However, if the firm is able to use ex-post events as part of the control environment (accidents being contractible for the firm), the regulator can achieve the first best through using an individual sanction or by using an enterprise sanction. These two cases are parallel to the cases of contractible individual safety efforts, as in these cases the firm, in principle, controls both safety decisions.

The insights arrived at are developed under the assumption that the individual has weak bargaining power due to a binding participation constraint. A change in power away from the firm towards the individual will change the safety incentives of both decision-makers. Consequently, the allocation of bargaining power between the two parties will impact optimal regulation. This study has analyzed the case for which firm safety efforts are non-contractible. However, if such efforts are contractible, then the position of the regulator is strengthened through the availability of policy instruments that in a more direct way influence the firm's safety choices i. e. standards, subsidies or taxes. This improved informational position, however, will not improve the situation given a joint use regime, as the first solution is attainable for this regime. The first best is unattainable in a regime that uses an exclusive enterprise sanction. Again contractible firm care will not improve on the situation as the inefficiency source is the non-contractibility of individual care. For the exclusive use of an individual sanction, contractible firm care might enable the regulator to steer firm care to the first best level e. g. by using safety standards while the individual sanction ensures that the first best individual care level is achieved. Individual liability and enterprise liability do equally well under performance pay for solvent decision-makers with similar liability probabilities. Individual liability, given a fixed wage contract, does better than enterprise liability. The opposite conclusion is possible only if the liability probability is significantly higher for the enterprise than for the individual.

The demand for improved prevention has created support for reforms that shift liability from physicians (malpractice law) to health care organizations. Our analysis, however, points to a situation where such a shift of liability might weaken preventive incentives. This can occur for health care organizations that do not have effective internal control systems. The targeting of physicians, where hospitals cannot specify a care level for physicians, will impact the safety efforts of both physicians and hospitals. The targeting of hospitals, on the other hand, only impacts the safety efforts of the hospital. This finding points to the possibility of individual liability outperforming enterprise liability, and that malpractice law (physician liability) in some situations can be an adequate regulatory instrument in ensuring patient safety.

There are other factors that are important in determining the relative attractiveness of the two liability regimes. Firstly, administrative costs (liability costs) may vary. Secondly, shifting liability from individuals to an enterprise may be advantageous as the latter is easier to identify ("avoid disappearing defendants") and because of judgment-proofness considerations. Thirdly, the relative attractiveness also depends on the demand for and structure of liability insurances, as such institutions tend to dilute safety care incentives (moral hazard). Fourthly, a complete discussion of liability should also consider error reporting incentives. Future research should, in the presence of several injurers that are contractually connected, consider the efficiency of other liability rules. If individual safety care is observable, one obvious candidate is the negligence rule. Another extension would be to consider the implications of firm safety efforts being unobservable for the employees of the firm.

Appendix A: Second order conditions for problems (8), (11), (13), (17), (28) and (32)

The second order condition for the problem of the regulator (see 8) is;

$d = \begin{vmatrix} S''_{ee} & S''_{eE} \\ S''_{Ee} & S''_{EE} \end{vmatrix} > 0$, where d is the determinant of the Hesse matrix.

$d = P''_{ee}P''_{EE} - P''_{eE}P''_{Ee} > 0$ is fulfilled from (3).

The second order condition for the problem of the individual (see 11) is:
$U''_{ee} = -P''_{ee}(E, e)[\alpha D + st]\alpha D < 0$, which is fulfilled from (1) and $\alpha > 0$.

The second order condition for the problem of the firm, when individual effort is non-contractible (see 13), is;

$$C''_{EE}(\star) = \{P''_{EE}(\star) + [2P''_{Ee}(\star) + P''_{ee}(\star)e'_E(\star)]e'_E\}\Psi + [P'_e(\star)\Psi + k]e''_{EE}(\star) > 0 \qquad (44)$$

Evaluating this condition in optimum using $e'_E(\star) = -\frac{P''_{eE}(\star)}{P''_{ee}(\star)}$ (see footnote 6) leads to the first term in (44) becoming $[\frac{P''_{EE}(\star)P''_{ee}(\star) - (P''_{Ee}(\star))^2}{P''_{ee}(\star)}]\Psi$, which from (3) is strictly positive meaning that (44) is always fulfilled for $e''_{EE}(\star) = 0$. The second term of (44) is evaluated by inserting the first order condition of the individual, $P'_E(\star) = -\frac{k}{\alpha D + st}$ (see 11), which implies that the second term can be written as follows; $-\frac{[\beta D + rT]}{\alpha D + st}ke''_{EE}(\star)$. This term is zero for *JS* (see 19). Thus $C''_{EE}(\star) > 0$. For *EL* and *IL* $\frac{[\beta D + rT]}{\alpha D + st} < 0$, thus a sufficient condition for $C''_{EE}(\star) > 0$ is $e''_{EE}(\star) \leq 0$.

The second order condition for the problem of the regulator (see 17) is $S''_{EE} > 0$. Assuming that all third derivatives of the accident probability function are zero yields $S_{EE} = \left[P''_{EE} + P''_{ee}(e'_E)^2 + 2P''_{eE}e'_E\right]D,$ which from (3) is strictly positive.

The second order condition for the problem of the firm (see 28) is;
$d_F = \begin{vmatrix} C''_{bb} & C''_{bE} \\ C''_{Eb} & C''_{EE} \end{vmatrix} > 0$, where the determinant of the Hesse matrix
$d_F = C''_{bb}C''_{EE} - C''_{bE}C''_{Eb} > 0$. Assuming that all third derivatives of the accident probability function are zero yields the following expressions:

$$C''_{Eb} = C''_{bE} = \left[P''_{Ee} - P''_{ee}e_E\right]e'_b\Psi = 0 \tag{45}$$

$$C''_{bb} = P''_{ee}(e'_b)^2\Psi > 0 \tag{46}$$

$$C''_{EE} = \Psi(P''_{EE} + P''_{ee}(e'_E)^2 + 2P''_{eE}e'_E) > 0. \tag{47}$$

Substituting for e'_E in (45), it follows that $C''_{Eb} = C''_{bE} = 0$. From (46) and (47), it follows that C''_{bb} and C''_{EE} are strictly positive. The second order condition is thus fulfilled. The second order condition for the problem of the regulator (see 32) is $S''_{TT}(\star)S''_{tt}(\star) - S''_{Tt}(\star)S''_{tT}(\star) > 0$.

Appendix B: The partial effects of T and t on E

$E'_T = -\frac{C''_{ET}(\star)}{C''_{EE}(\star)}$ and $E'_t = -\frac{C''_{Et}(\star)}{C''_{EE}(\star)}$ where $C''_{EE}(\star) > 0$ (see 44), $C''_{ET}(\star) = \left[P'_E(\star) + P'_e(\star)e'_E(\star)\right]r$ and $C''_{Et}(\star) = \left[P''_{EE}(\star)\Psi + P''_{ee}(\star)e'_E(\star)\right]e'_t + P'_E(\star)s + \left[P'_e(\star)\Psi + k\right]e''_{Et}$. $C''_{ET}(\star)$ and $C''_{Et}(\star)$ are indeterminate, thus $E'_T \geq (<)0$ and $E'_t \geq (<)0$.

Appendix C: The first order conditions for problem (17)

(1)–(5) ensure interior solutions to problem (17). Solving problem (17) yields;

$$S'_T(E, e) = \left[P'_e(\star)D + k\right]E'_T(\star)e'_E(\star) + \left[P'_E(\star)D + K\right]E'_T(\star) = 0 \tag{48}$$

$$S'_t(E, e) = \left[P'_e(\star)D + k\right]\left(E'_t(\star)e'_E(\star) + e'_t(\star)\right) + \left[P'_E(\star)D + K\right]E'_t(\star) = 0 \tag{49}$$

Appendix D: The optimal sanction when the firm issues a sanction being contingent upon the occurrence of accidents

The objective functions of the individual and the firm follows from replacing *be* in (6) and (7) with $zfP(E,e)$, where z is the probability of the individual being sanctioned by the firm and f is the firm penalty. This procedure yields the following objective functions;

$$U(E,e) = A - zfP(E,e) - P(E,e)\alpha D - P(E,e)st - ke \geq \bar{U} \tag{50}$$

$$C(E,b) = A + P(E,e)\beta D + P(E,e)rT + KE \tag{51}$$

$$S(E,e) = P(E,e)D + KE + ke \tag{52}$$

In the final stage, the individual maximizes (50) with respect to e, which yields; $U'_e(e;E,b,t) = -P'_e(E,e)(\alpha D + st + zf) - k = 0$, which again can be expressed as;

$$-P'_e(E,e)[\alpha D + st + zf] = k \tag{53}$$

The first order condition of the individual, (53), defines the following response function;

$$e = e(E,t,f) \tag{54}$$

The firms' maximization problem becomes;

$$\underset{E,b}{Min}\, C(E,b,e) = \bar{U} + P(E,e)\Omega + ke + KE \;\; s.t. \; e = e(E,t,f)$$
$$\text{where} \quad \Omega \equiv (\alpha + \beta)D + rT + st.$$

The first order conditions for this problem become (assuming interior solutions);

$$C'_f(E,b) = e'_f(\star)\left[P'_e(\star)\Omega + k\right] = 0 \tag{55}$$

$$C'_E(E,f) = \left[P'_E(\star)\Omega + K\right] + e'_E(\star)\left[P'_e(\star)\Omega + k\right] = 0 \tag{56}$$

By using (53), the two conditions can be expressed as;

$$zf = \beta D + rT \tag{57}$$

$$P'_E(E, e(E, b, t)) = -\frac{K}{\Omega} \tag{58}$$

Equation (58) defines the response function of the firm;

$$E = E(T, t) \tag{59}$$

The regulator minimizes (52) given (54), (57) and (59). Solving this problem produces the following first order conditions for the regulator;

$$st + zf - (1-\alpha)D = rT + st - (1-\alpha-\beta)D = 0 \tag{60}$$

By inserting (57), (60) can be expressed as;

$$st + rT = \gamma D \tag{61}$$

By inserting (61) into (57), we arrive at the following expression for the optimal firm sanction;

$$zf = \beta D + rT = (1-\alpha)D - st \tag{62}$$

This regime produces the first best. This is seen by inserting the sanction levels in (61) and (62) into (53) and (58).

Now consider *ES* $(t = 0)$. From (61) we get $r\bar{T}^{EL} = \gamma D$. By inserting this optimal enterprise sanction level into (62), the optimal internal penalty becomes $z\bar{f}^{ES} = (\beta + \gamma)D$. For *IS* $(T = 0)$, the optimal individual sanction level $s\bar{t}^{IL} = \gamma D$ (see 61) and the optimal internal penalty is $z\bar{f}^{IS} = \beta D$ (see 20) and is independent of the optimal individual sanction level.

Appendix E: The first order conditions for problem (28)

The first order conditions for problem (28) become;

$$C_b'(E,b) = e_b'(*)\left[P_e'(*)\Psi + k\right] \ \geq (<)0 \tag{63}$$

$$C_E'(E,b) = \left[P_E'(*)\Psi + K\right] + e_E'(*)\left[P_e'(*)\Psi + k\right] \geq (<)0 \tag{64}$$

From (1)–(5) and $\Psi > 0,$ (63) and (64) are binding. Thus we get;

$$P_e'(E, e(E,b,t)) = -\frac{k}{\Psi}$$

$$P_E'(E, e(E,b,t)) = -\frac{K}{\Psi}$$

Appendix F: The first order conditions for problem (32)

(1)–(5) ensures interior solutions. Solving the problem of (32) therefore yields the following equation system;

$$S_T'(E,e) = \left[P_e'(*)D + k\right](E_T'(*)e_E'(*) + e_b'(*)b_T'(*)) + \left[P_E'(*)D + K\right]E_T'(*) = 0 \tag{65}$$

$$S_t'(E,e) = \left[P_e'(*)D + k\right](E_t'(*)e_E'(*) + e_b'(*)b_t'(*) + e_t'(*)) + \left[P_E'(*)D + K\right]E_t'(*) = 0 \tag{66}$$

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