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Efficiency and traffic safety with pay for performance in road transportation

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ABSTRACT

We propose a theoretical model in order to study the behavior of a road transport company and a driver. The driver is supposed to face a pay for performance contract. The expected profit for the company and the expected utility for the driver depend on the input chosen by themselves and the other actor. By analyzing the possible interaction going on between the actors in a simultaneous game and the two possible leader-follower games, it is seen that the efforts could be strategic complements, independent or strategic substitutes. In cases where the efforts are strategic complements, and the expected profit for the company and the expected utility for the driver are increasing in the other actor's effort, leader-follower games trigger higher accident risks than the simultaneous game. If efforts are strategic complements, and the expected profit and utility are decreasing in the other actor's effort, leader-follower games produce lower accident risks than when the actors move simultaneously. Presuming that the transport company is the principal and the driver is the agent, we deduce an optimal pay contract. The optimal contract is characterized by a pay for performance contract where the driver's share of net revenue becomes higher the higher influence a marginal increase in her effort has on the net revenue, the lower influence a marginal increase in her effort has on the probability of accidents, and the lower the loss the company experiences if an accident occurs. When such a contract is used, the driver faces a situation where the transport company's interests are perfectly internalized, meaning that the company also maximizes the sum of the expected profit and utility. However, since accidents also mean costs for others apart from the driver and the company, public regulation is needed to ensure overall welfare.

1. Introduction

Companies that supply professional transport services on roads employ workers who drive the carrying vehicles. The wage contracts in road transportation, as in the labor market generally, might vary from fixed payment per time unit to a total flexible wage, dependent on observable and verifiable variables correlated with the worker's performance. The theoretical arguments for insisting on some kind of pay for performance wage contracts stem from principal-agent theory where the workers become motivated to behave efficiently when their wages are dependent on the company's economic result.

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Flexible wage payment is also desirable in order to ensure that high skilled and qualified workers find it attractive to sign contracts with the company. Another aspect of wage payment often highlighted in the principal-agent literature is that the wage payment contracts should be designed in order to share risks among the company and the workers. (E.g. Alchian and Demsetz 1972; Stiglitz 1974; Holmstrom 1979; Lazear and Rosen 1981; Stiglitz 1987; Jensen and Murphy, 1990; Bergland 1995; Grepperud and Pedersen 2006). An essential assumption in the principal-agent models is that the company does not directly observe the workers' effort, implying there is a pervasive tendency for shirking among the workers. Hence, an important conclusion from such models is that adopting some kind of pay for performance in wage contracts is an efficient way for the company to ensure that workers have incentives to be productive.

On the other hand, researchers engaged in traffic safety have questioned in theoretical and empirical studies whether payment systems rewarding drivers' production performance may influence the traffic safety outcomes negatively, see, for instance, Freyer et al. (1997), Johansson et al. (2010), Williamson and Friswell (2013), Soccolich et al. (2013), Mooren et al. (2014), Newnam and Goode (2015), Phillips et al. (2015), Thompson et al. (2015), Nævestad et al. (2015), Newnam and Oxley (2016), Warmerdam et al. (2017) and Nævestad et al. (2018). One of the points made in these works are that if the drivers face pay for performance contracts, their level of effort will be determined by their eagerness to make money. For instance, in order to obtain high wages, they will drive faster and pay less attention, implying that traffic accident risks increase.

Nævestad et al. (2018) give a comprehensive literature overview on research regarding traffic accident risks in professional road transportation. In their discussion, the traffic accident risk factors fall into different groups. They distinguish between risk factors related to the drivers, the vehicles, the roads, the road environment, the working conditions and fatigue among drivers. Their article focuses in particular on developing management strategies for reducing traffic accident risks among road transport operators. Other researchers have discussed different regulatory tools that may decrease accident risks, see, for instance, Bjørnskau and Elvik (1992), Persson and Odegaard (1995), Peirson et al. (1998), Jara-Diaz et al. (2000), Dickerson et al. (2000), Jørgensen and Pedersen (2002), Ryeng (2012), Bentham (2015), Haddak et al. (2016) and Bergland and Pedersen (2018). Researchers have also been interested in the drivers' perceptions and reactions to the risks they face – see, for instance, Jørgensen (1993), Jørgensen and Polak (1993) and Vukina and Nestić (2015). Game theoretical approaches to the possible strategic interactions going on between road users and the consequences for accident risks have also been studied – see, for instance, Pedersen (2003), Andersson and Auffhammer (2014), Elvik (2014), Arbis et al. (2016) and Bjørnskau (2018).

Even though the traffic safety interdisciplinary research so far has revealed many possible risk factors and safety challenges in professional road transportation, to our knowledge no-one has conducted a formal economically analysis describing and discussing pay for performance contracts between a transport company and a driver. Carrying out such an analysis is interesting for several reasons. Economic theory emphasizes the favorable efficiency properties of flexible payment systems to the drivers, while traffic safety researchers emphasize the negative impact such contracts might have on accident risks. Hence, there is a need to clarify the reasoning behind these different views. The fact that pay for performance contracts seem to be widely used in professional road transportation is another reason why economic modeling is interesting. Thirdly, even though many researchers have been engaged in modeling strategic interaction between road users, application of game theory to analyze the relation between management and workers within the transport companies is not that often conducted. Hence, with the aim of filling this gap, we will analyze both the efficiency and traffic safety consequences of practicing pay for performance wage contracts. In particular, we will try to identify situations where pay for performance leads to relatively high accident risks, and see whether the opposite also could happen. Moreover, we are interesting to deduce an optimal wage contract, and discuss whether, and eventually to what extent, such a contract should be based on pay for performance.

The first part of our analysis studies the relation between the transport company and the driver as a game for a given wage contract, where each of the actors chooses efforts affecting both productivity and traffic safety. The discussion contains the traditional definition of strategic complements and substitutes in the industrial organization literature (see for instance Bulow et al., 1985). We identify situations where a higher level of effort from one of the actors induces a higher effort from the other actor and term such cases as efforts being strategic complements. The opposite situations, where an increase in one of the actors' effort gives a lower effort from the other actor, are termed cases where the efforts are strategic substitutes. Such a modeling represent an extension and refinement of the framework used for discussing contracts in the transportation field. Moreover, we use this game theoretical analysis as an input for deducing an optimal wage contract in a principal – agent model, where the transport company is the principal and the driver is the agent. Unlike the traditional principal – agent models, where the principal only chooses the wage contract based on the agent's participation constraint and her behavioral reaction on different contracts, the principal in our model is supposed to adjust her effort that affects both the production and traffic accident risks.

In Section 2 we propose a conceptual model where a transport company may affect its expected profit and the drivers expected utility by choosing effort in production. The driver's effort in production also influences the company's expected profit and her own expected utility. Section 3 contains a discussion on the possible strategic interactions going on between the company and the driver for a given wage contract. Using a traditional principal-agent framework, we deduce the optimal linear wage contract between the company and the driver in Section 4. In Section 5 we discuss the driver's and the company's behavior in an overall social welfare perspective. Finally, Section 6 offers a summary of the main theoretical conclusions and discusses limitations and possible extensions of our analyses.

2. The model

To analyze behavior in the road transport industry, we present a simple model describing the company's choice of an input in production and a driver's effort at work. Suppose that a typical transport company faces an exogenous production technology and exogenous prices for its transport services. The company's scale of production is determined by the choice of the number of vehicles it has, i.e. duplication of identical production units. To simplify, we assume that the company makes use of one driver for each vehicle. When these assumptions hold, we can formulate a net revenue function, R, dependent on the operational input and effort values chosen by the company and by the driver. R measures the income from production minus operational costs the company has in the same period, except the cost of hiring the driver and the costs the company suffers if an accident occurs.[1] Suppose t symbolizes the effort level chosen by the company and e the effort level chosen by the driver, then $R = R(t, e)$. If we take into account labor and accident costs as well, the expected profit for the firm in the period, π, becomes

$$\pi = R(t, e) - w - p(t, e)L^C \tag{1a}$$

where w is the wage paid to the driver in the period, p is the probability for an traffic accident and L^C is the loss experienced by the transport company if an accident occurs, for simplicity assumed to be unaffected by the parties' efforts.[2] L^C measures the costs of damage to vehicle and cargo if an accident occurs, and possible losses due to downtime and assignments that the company may experience in the case of an accident. Moreover, we only consider one type of a traffic accident, defined by an exogenous probability function, $p = p(t, e)$. Similar to the net revenue, this means that the accident risk is dependent on the parties' effort levels. Regarding the revenue and probability functions, the following properties are supposed to hold:[3]

$$R_t > 0,\ \ R_e > 0, R_{tt} < 0, R_{ee} < 0, R_{et} > 0\ \ p_t > 0,\ \ p_e > 0, p_{tt} > 0, p_{ee} > 0 \text{ and } p_{et} > 0 \tag{1b}$$

First, (1b) means that increased individual efforts imply higher production value ($R_t > 0$ and $R_e > 0$), but steadily at a lower rate ($R_{tt} < 0$ and $R_{ee} < 0$). Moreover, it seems reasonable to assume that higher effort from the company increases the marginal productivity from the driver's effort[4] ($R_{et} > 0$). Additionally, it is assumed that higher production efforts from the parties make the transport operations on the road more dangerous ($p_t > 0$ and $p_e > 0$) and that these effects become stronger the higher the efforts are originally ($p_{tt} > 0$ and $p_{ee} > 0$). It is also assumed that the increase in accident probability for higher effort on the part of the driver grows as the company steps up its own effort ($p_{et} > 0$).

In our reasoning, we could think of t as a variable describing the operational intensity controlled by the company. For instance, this variable could be measured by the total hours of operation per period, the number of transport assignments, transported volumes, or distance, or an index that builds on a combination of all of these measures. Moreover, we consider e as the driver's intensity in undertaking the transport task. The driver's intensity relates, for instance, to traffic speed, effort and time used in loading and unloading the vehicle in operation, the driver's use of resources in planning and preparing for transport assignments, or an index that builds on a combination of all of these variables. It is often the case that the driver does not exert a single dimensional effort. She may be involved in many related activities associated with undertaking the transport mission. The driver performs multi-tasking, where these tasks might affect both traffic safety and productivity in a more complex pattern than assumed in (1b). Effort in one task, for instance preparing vehicle and use of equipment (e.g. snow chains), might reduce short run productivity and at the same time increase road safety. Hence, considering this specific task isolated, the first order derivative with respect to the driver's effort in (1b) are the opposite. Specifying only one action variable, interpreted as an index of combined variables for each of the actors, represent of course a simplification of reality. However, we have chosen to keep the model as tractable and simple as possible, in order to concentrate on the strategic interdependencies between driver and company.[5] Now, let us assume that the driver faces a linear pay contract given by

$$w = a + bR(t, e) \tag{2}$$

where a is a fixed wage, independent of the company's revenue and b is the payment to the driver per net revenue unit obtained in the actual period. We restrict ourselves to discussing cases where $0 \leq b \leq 1$, where $b = 0$ means fixed payment, and $b = 1$ implies a perfectly flexible wage contract. In practice one often finds that driver's wage is partly dependent on production performance, $0 < b < 1$. In reality, the driver's performance can be measured by, for instance, the number of

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[1] In reality, the company might have both revenue and costs in inserting efforts in production. Suppose for instance that $R = R(e, t) = F(t, e) - v(t, e)$, where $F(t, e)$ and $v(t, e)$ measure the company's revenue and costs respectively. Without loss of generality, however, we have dropped to specify the costs, and are interpreting $R(e, t)$ as a net revenue for the company.

[2] In general, accident losses are often presumed to be positively correlated with less risk attention and more production intensive individual behavior, see, for instance, Jørgensen and Pedersen (2002) and Pedersen (2003).

[3] Here and throughout the text we use the conventional description $A_x = \frac{\partial A}{\partial x}$ in order to simplify our equations

[4] In ordinary production theory the inputs are often regarded as technical complements in production.

[5] In traffic safety research, it is sometimes considered that the driver assigns an effort to shortening the travel time and an effort for securing the traffic safety simultaneously, see for instance in Risa (1994) and Jørgensen and Pedersen (2002). In the latter work it is modeled a level of care, additional to the choice of speed among drivers, where an increased caretaking means lower accident risks. For further examples on multitask environments in principal – agent modeling, see also Holmstrom and Milgrom (1991) and Laffont and Martimort (2002). We do not pursue this extended analysis here.

kilometres driven, the number of tons carried, the number of ton kilometres produced, or other variables concerning production. For simplicity, here we discuss a wage consisting of a fixed element, and an element dependent on the company's net revenue. This means that we suppose that the net revenue stemming from the driver's production activity is 'highly correlated' with the driver's production. Moreover, the driver's expected utility function is supposed to be given by

$$U = w - g(e) - p(t, e)L^D \tag{3a}$$

where g(e) is the driver's disutility function of effort, and L^D is the loss experienced by the driver if an accident occurs. The driver's loss measures economic factors as possible losses in bonuses and occupation and fees covered by the driver should an accident happen. In addition, L^D also contains physical and mental health consequences that might occur in the event of an accident. In accordance with the standard principal-agent models, it is supposed that the disutility of the driver's effort is convexly increasing in effort, i.e.

$$g_e > 0 \text{ and } g_{ee} > 0 \tag{3b}$$

To be aware of the parties' interrelation given by the model in (1)-(3), let us see how the expected profit for the company is affected by marginal changes in the driver's effort. By using (1) and (2), and differentiating the expected profit w.r.t. e, we obtain

$$\pi_e = (1-b)R_e - p_eL^C \geq (<)0 \text{ as } (1-b)R_e \geq (<)p_eL^C \tag{4}$$

From (4) we see that a more intense production effort from the driver has two different effects on the expected profit for the company. The company obtains an increase in the part of the net revenue that it keeps, $(1-b)R_e$. However, the increased probability of accidents that follows from a higher e means a negative impact on expected profits, p_eL^C. Whether the sum is positive, zero, or negative, indicating whether the company would prefer a more intense driver's effort or not, is dependent on the size of these effects. Moreover, we note that the higher b is, the lower R_e is, the higher p_e is, and the higher L^C is, the more likely it becomes that the company's expected profit reduces as e is stepped up.

Let us now do a similar analysis on how marginal changes in t affect the driver's utility, i.e.

$$U_t = bR_t - p_tL^D \geq (<)0 \text{ as } bR_t \geq (<)p_tL^D \tag{5}$$

From (5) we see that it is also ambiguous whether the driver would prefer a more or less intense transport operation from the company. If the driver obtains an increase in her variable wage that more (less) than compensates for the increased expected losses following from a higher t, her expected utility will increase (decrease). It follows that it becomes more likely that the driver is positively affected by an increase in t for higher values of b and R_t and lower values of p_t and L^D.

In the way the model is constructed, the company and the driver have partially the same interests, even though the company prefers low wages to high wages, while the driver has the opposite preference. Firstly, it follows that both parties prefer low accident risk to high accident risk, and, secondly, when $0 < b < 1$, they are both interested in high net revenue.[6] These interdependencies between the actors' economic interests are the background for studying possible strategic interaction between the parties when they are supposed to act rationally.

3. Optimal behavior and strategic interactions for a given linear pay contract

An exogenous pay contract, defined by a and b in (2), might stem from negotiations between representatives of the drivers' labour union and the road transportation companies' industry organization. In order to study the transport company's and the driver's optimal behavior for a given wage contract, we first look into the problem where the parties are supposed to choose their efforts simultaneously, without knowing the other's actions. Secondly, we look into the game where the company chooses its effort first, and the driver, after observing the other's effort, adjusts her effort. Thirdly, we study the case where the driver acts as a leader, choosing her effort level first, and the company, after being aware of her effort, chooses its operation intensity. Which of the proposed games is most realistic depends on the context. The simultaneous one describes a situation where the company's management is unaware of the actual choice made by the driver, and, analogously, the driver does not know the management's decision regarding the company's choice of input. If the company's decision comes first and the driver knows this decision, the company becomes the leader and the driver is the follower. If the managers of the company wait to see the driver's behavior before choosing the company's effort, we have the case where the driver is the leader and the company is the follower. After we have deduced the solutions of these three games, we will compare the different cases and discuss similarities and differences in the outcomes.

3.1. Simultaneous moves

Using the definitions in (1) and (2), maximizing the expected profit for a given wage contract and a given level of effort chosen by the driver, gives us the following 1. and 2.order conditions

$$\pi_t = (1-b)R_t - p_tL^C = 0 \text{ and } \pi_{tt} = (1-b)R_{tt} - p_{tt}L^C < 0 \tag{6}$$

[6] If $b = 0$, the driver would have no interest in doing more than necessary (to keep her job), and if $b = 1$, there would be no incentive for the company's management to do something that affects the net revenue.

where it follows directly from the assumptions made in (1b) that the 2.order condition holds. The optimal level of t is characterized by a situation where the company's increase in its share of the revenue for the last unit inserted in transport operations, $(1-b)R_t$, equals the expected increase in its loss if an accident occurs, $p_t L^C$.

Analogously, using the definitions in (2) and (3), maximizing the expected utility for a given wage contract and a given level of t, means that the 1. and 2.order conditions for an optimal e can be written as

$$U_e = bR_e - g_e - p_e L^D = 0 \text{ and } U_{ee} = bR_{ee} - g_{ee} - p_{ee} L^D < 0 \tag{7}$$

where it follows from the assumptions made in (1b) and (3b) that the 2.order condition is satisfied. The optimal e is obtained when the driver's part of the increased net revenue for a unit effort level, $bR_e - g_e$, is equal to the higher expected loss from accidents the same effort unit gives, $p_e L^D$. The first expressions in ((6) and (7) are two equalities together defining the Nash-equilibrium in the game where the parties pick their effort levels simultaneously. The solution of the simultaneous game illustrates that the actors for a given pay for performance contract are both concerned about the positive effects higher efforts have on their portion of the income and the negative consequences flowing from expected higher accident risks. In the following, we denote the equilibrium values in the simultaneous case by (t^s, e^s).

Result 1. For a given pay for performance wage contract, the transport company and the driver in a simultaneous game inject efforts in production until their individual marginal net gains through increased income are equal to their experienced marginal increase in expected losses caused by a higher accident probability.

3.2. The company moves first

We now assume that the transport company chooses its operational effort, t, before the driver chooses her level of effort. We study this case by backward induction, meaning that we first deduce the driver's reaction to different levels of t. Implicitly the first equation in (7) defines the driver's response to the company's actual choice of effort, i.e. $e = e(t)$. Differentiation of the first equation in (7) with regard to t then gives us

$$\frac{de}{dt} = -\frac{U_{et}}{U_{ee}} = -\frac{bR_{et} - p_{et} L^D}{bR_{ee} - g_{ee} - p_{ee} L^D} \geq (<) 0 \text{ and } U_{et} = bR_{et} - p_{et} L^D \geq (<) 0 \tag{8}$$

It follows from (8) that the driver will react either by increasing or decreasing her level of effort when the company steps up its effort, depending on whether her marginal expected utility with regard to her own effort is increased or decreased as the company becomes more intensive in its operations. There are two effects to consider, drawing in opposite directions. First, when the company injects more effort, the driver's effort becomes more valuable in creating a positive wage increase from the net revenue, i.e. bR_{et} is positive. However, an increased effort from the company also means an increase in the marginal growth in probability for accidents with regards to the driver's effort, implying reduced expected marginal utility from injecting effort, $p_{et} L^D$. Whether the production term or the risk term dominates, is ambiguous. If the driver increases (decreases) her effort when the company steps up its effort, we follow the ordinary concept in game theory and say that the efforts are strategic complements (substitutes) seen from the company's perspective, see, for instance, Bulow et al. (1985) and Pedersen (2003).

Now, we consider the company's optimal behavior, given the response from the driver. Using the expressions in (1), (2) and (8) implies that the 1.order condition for an optimal t now must satisfy[7]

$$\frac{d\pi}{dt} = (1-b)R_t - p_t L^C + \pi_e \frac{de}{dt} = (1-b)R_t - p_t L^C + \left[(1-b)R_e - p_e L^C\right] \frac{de}{dt} = 0 \tag{9}$$

From comparing equation the first equation in (6) and the equation in (9), we see that the leading company, in addition to noting the direct effect t has on its expected profit, is interested in how the driver reacts by changing her level of e as t is increased or decreased, and whether the driver's response increases or decreases the company's expected profit. This is measured by the term $\pi_e \frac{de}{dt}$. We have four possible cases. First, if the reaction from the driver is positive for marginal changes in t, i.e. $\frac{de}{dt} > 0$ because $U_{et} > 0$, and the company's expected profit is growing in e, $\pi_e > 0$, the company will set a higher t than in the simultaneous case, and the response from the driver is a higher e. Second, if the reaction is still positive and the expected profit is decreasing in e, $\pi_e < 0$, the company will prefer a lower intensity effort from the driver, and therefore, reduces its effort. Third, if the driver reacts by reducing her effort as t steps up, $\frac{de}{dt} < 0$ because $U_{et} < 0$, and the profit is increasing in e, $\pi_e > 0$, the company will set a lower t to induce higher effort from the driver. Finally, when both expressions are negative, i.e. $\frac{de}{dt} < 0$ because $U_{et} < 0$ and $\pi_e < 0$, the company chooses a low t in order to force the driver to choose a low e. It is also seen that if $\frac{de}{dt} = 0$ or $\pi_e = 0$, or both are equal to zero, both actors choose the same level of effort as in the simultaneous case. The first equation in (7) and the equation in (9) are defining the Nash-equilibrium in the game where the company makes its effort first and the driver observes its effort and subsequently decides her level of effort. In the following, we denote these equilibrium values by (t^L, e^F).

[7] Here we have dropped to present the 2.order condition in the text. However, it is seen that the sufficient condition is given by $\frac{d^2\pi}{dt^2} = (1-b)R_{tt} - p_{tt} L^C + 2[(1-b)R_{et} - p_{et} L^C] \frac{de}{dt} + [(1-b)R_{ee} - p_{ee} L^C][\frac{de}{dt}]^2 + [(1-b)R_e + p_e L^C] \frac{d^2 e}{dt^2} < 0$, meaning that the assumptions already made are not sufficient to secure that the 2.order condition is satisfied. However, in the following analysis, we presume that this condition holds.

Result 2. In the case where the transport company decides first, it will choose a higher effort than in the simultaneous case when $\pi_e > 0$ and $U_{et} > 0$ and when $\pi_e < 0$ and $U_{et} < 0$ are satisfied. When $\pi_e < 0$ and $U_{et} > 0$ and when $\pi_e > 0$ and $U_{et} < 0$ hold, the company will choose a lower level. The driver, being the follower, will choose a higher effort than in the simultaneous case when $\pi_e > 0$ and $U_{et} > 0$ and when $\pi_e > 0$ and $U_{et} < 0$ are satisfied. If $\pi_e < 0$ and $U_{et} > 0$ and if $\pi_e < 0$ and $U_{et} < 0$ hold, the driver will inject a lower level.

3.3. The driver moves first

Now the company chooses its level of effort according to the first equation in (6). From this equation the company's optimal value of t is dependent on e, meaning that this equation implicitly defines the company's response function $t = t(e)$. Differentiating the first equation in (6) with regard to e, gives us

$$\frac{dt}{de} = -\frac{\pi_{et}}{\pi_{tt}} = -\frac{(1-b)R_{et} - p_{et}L^C}{(1-b)R_{tt} - p_{tt}L^C} \geq (<)0 \text{ as } \pi_{et} = (1-b)R_{et} - p_{et}L^C \geq (<)0 \tag{10}$$

The slope of the reaction function in (10) is dependent on the sign of π_{et}. If the marginal profit in t is increasing (decreasing) in e, the efforts become strategic complements (substitutes) seen from the perspective of the driver. Now, the driver will maximize her utility, taking into account the reaction of the company. Using (2), (3) and (10), then gives us the following 1.order condition[8]

$$\frac{dU}{de} = bR_e - g_e - p_eL^D + U_t\frac{dt}{de} = bR_e - g_e - p_eL^D + \left(bR_t - p_tL^D\right)\frac{dt}{de} = 0 \tag{11}$$

If we compare (11) and the first equation in (7), it is seen that the driver, in addition to evaluating the direct effect e has on her expected utility, must also be aware of the indirect effect e has on the company's effort, and whether a marginal increase in the company's effort increases or reduces her expected utility. This indirect effect is measured by the term $U_t\frac{dt}{de}$. In the case where this effect is positive, either when both U_t and $\frac{dt}{de}$ are positive or negative, the driver as the leader will choose a higher level of effort. When $\frac{dt}{de} > 0$, this will encourage the company to increase its effort, which is favourable for driver as $U_t > 0$. In the case where the slope of the reaction function is negative at the same time as $U_t < 0$, the increased effort for the driver will reduce the company's effort, which increases the expected utility. If the factors have opposite signs, the driver will choose a lower effort than in the simultaneous case. When the slope of the reaction function is negative and $U_t > 0$, the lower effort means that the company increases its effort compared with the simultaneous case, which is favorable for the driver. Finally, when the slope of the reaction function is positive and $U_t < 0$, the driver's lower effort reduces the company's effort, increasing the driver's utility. If $U_t = 0$ or $\frac{dt}{de} = 0$, or both are equal to zero, the solution will be the same as in the simultaneous case. The first equation in (6) and the equation in (11) define the Nash-equilibrium in the game where the driver moves first, and the company observes her effort and chooses its input level. In the following, we denote these equilibrium values by (t^F,e^L).

Result 3. In the case where the driver is the leader, she will choose a higher effort than in the simultaneous case when $U_t > 0$ and $\pi_{et} > 0$ or when $U_t < 0$ and $\pi_{et} < 0$ are satisfied. If $U_t > 0$ and $\pi_{et} < 0$ or if $U_t < 0$ and $\pi_{et} > 0$ hold, she will choose a lower level. The transport company, being the follower, will choose a higher effort than in the simultaneous case when $U_t > 0$ and $\pi_{et} > 0$ or when $U_t > 0$ and $\pi_{et} < 0$ are satisfied. If $U_t < 0$ and $\pi_{et} > 0$ or if $U_t < 0$ and $\pi_{et} < 0$ hold, the company will make a lower level of effort.

3.4. Comparing the different games and outcomes

From the analyses it is seen that the signs of U_t, π_e, U_{et} and π_{et}, crucial for the actual choices of e and t in the different cases, can be either positive, zero or negative, and generally all combinations of signs are possible. From the equations in (4), (5), (8) and (10) it follows that the signs of these functions is conditional on whether the marginal effects on the actors' portion of the net revenue – being positive – or the effects on the expected accident losses – being negative – dominate or not. In order to compare and discuss the consequences for traffic safety from the different games, we have in Tables 1 and 2 summarized the results found in the analyses of the three proposed games. In Table 1 we have presented the case where the company is the leader and the driver is the follower. The lines in Table 1 illustrate whether the company's expected profit increases, is zero, or reduces as the driver steps up her effort, while the columns tell us whether the efforts are strategic complements, independent or strategic substitutes in the eyes of the company. All together nine combinations become possible and we compare the outcomes from the situations where the company is the leader with the simultaneous case. In addition to the effort levels, we have also calculated the accident probabilities for the different cases, where the following denotations are used: $p^S = p(t^S,e^S)$, $p^{LF} = p(t^L,e^F)$ and $p^{FL} = p(t^F,e^L)$. For the case where the driver is the leader and the company is the follower, Table 2 presents the different situations. Here the lines illustrate whether the expected utility

[8] The second order condition for this problem is given by $\frac{d^2U}{de^2} = bR_{ee} - g_{ee} - p_{ee}L^D + 2(bR_{et} - p_{et}L^D)\frac{dt}{de} + (bR_{tt} - p_{tt}L^D)(\frac{dt}{de})^2 + (bR_t - p_tL^D)\frac{d^2t}{de^2} < 0$. As commented on when considering the case where the company moves first, also in this case extra assumptions are needed in order to secure that the 2.order condition is satisfied. In the following discussions, we presume it holds.

Table 1
Comparing the case where the company is the leader with the simultaneous case.

	$U_{et} > 0$, $\frac{de}{dt} > 0$ strategic complements	$U_{et} = 0$, $\frac{de}{dt} = 0$ strategic independent	$U_{et} < 0$, $\frac{de}{dt} < 0$ strategic substitutes
$\pi_e > 0$	$t^L > t^S$, $e^F > e^S$, $p^S < p^{LF}$	$t^L = t^S$, $e^F = e^S$, $p^S = p^{LF}$	$t^L < t^S$, $e^F > e^S$, $p^S \lesseqgtr p^{LF}$
$\pi_e = 0$	$t^L = t^S$, $e^F = e^S$, $p^S = p^{LF}$	$t^L = t^S$, $e^F = e^S$, $p^S = p^{LF}$	$t^L = t^S$, $e^F = e^S$, $p^S = p^{LF}$
$\pi_e < 0$	$t^L < t^S$, $e^F < e^S$, $p^S > p^{LF}$	$t^L = t^S$, $e^F = e^S$, $p^S = p^{LF}$	$t^L > t^S$, $e^F < e^S$, $p^S \lesseqgtr p^{LF}$

Table 2
Comparing the case where the driver is the leader with the simultaneous case.

	$\pi_{et} > 0$, $\frac{dt}{de} > 0$ strategic complements	$\pi_{et} = 0$, $\frac{dt}{de} = 0$ strategic independent	$\pi_{et} < 0$, $\frac{dt}{de} < 0$ strategic substitutes
$U_t > 0$	$t^F > t^S$, $e^L > e^S$, $p^S < p^{FL}$	$t^F = t^S$, $e^L = e^S$, $p^S = p^{FL}$	$t^F > t^S$, $e^L < e^S$, $p^S \lesseqgtr p^{FL}$
$U_t = 0$	$t^F = t^S$, $e^L = e^S$, $p^S = p^{FL}$	$t^F = t^S$, $e^L = e^S$, $p^S = p^{FL}$	$t^F = t^S$, $e^L = e^S$, $p^S = p^{FL}$
$U_t < 0$	$t^F < t^S$, $e^L < e^S$, $p^S > p^{FL}$	$t^F = t^S$, $e^L = e^S$, $p^S = p^{FL}$	$t^F < t^S$, $e^L > e^S$, $p^S \lesseqgtr p^{FL}$

for the driver is increasing, constant or decreasing as the company increases its effort, while the columns express whether the efforts are strategic complements, independent or strategic substitutes seen from the perspective of the driver.

First we should note that the second line in Table 1, defined by $\pi_e = 0$, implies that $\pi_{et} = 0$, meaning that this second line corresponds to the second column in Table 2. Also the second line in Table 2 corresponds to the second column in Table 1 because $U_t = 0$ implies $U_{et} = 0$. Altogether, this means that if $U_t = 0$, $\pi_e = 0$, or both these are zero, then all cases give the same efforts, i.e. $t^L = t^S = t^F$ and $e^L = e^S = e^F$, and consequently the same accident risk, i.e. $p^S = p^{LF} = p^{FL}$. Furthermore we see from Table 1 that in the case of strategic complements, illustrated in the first column, the simultaneous game possibly gives both lower and higher accident risk than the case where the company is the leader. This depends on whether the expected marginal profit with regard to the driver's effort is positive or negative. If $\pi_e > 0$, the case of strategic complements means that both actors choose high efforts, resulting in relatively high accident risk, while the opposite is true if $\pi_e < 0$. In the case of strategic substitutes, illustrated in the third column in Table 1, the actors move in different directions regarding the efforts they make compared with the simultaneous case, meaning that the effect on accident risk is inconclusive.

The same observations are seen in Table 2 where we compare the case where the driver is the leader with the simultaneous case. From the first column, where the efforts are strategic complements seen from the driver, it follows that both actors have higher efforts in the leader-follower case than in the simultaneous case if $U_t > 0$ and lower efforts if $U_t < 0$. This means that the leader-follower model could both increase or decrease risks compared with the simultaneous case, dependent on whether the driver prefers higher effort from the company or not. On the other hand, when the efforts are strategic substitutes, seen in the third column in Table 2, it is inconclusive whether the simultaneous case or the leader-follower case gives the highest accident risk or not. This is because the actors' efforts, compared with the simultaneous case, move in a different direction.

Moreover, we summarize some of the cases from Tables 1 and 2 by drawing conceptual figures, consisting of the two reaction functions and the iso-profit and indifference curves for the leading company and the leading driver respectively, see Figs. 1–6 below. In all diagrams, curves representing the driver are colored red, and curves representing the company are colored blue. The intersection labelled S represents the simultaneous move solution, the point of tangency labelled C represents the solution when the company is the first mover, and the point of tangency labelled D represents the solution when the driver is the first mover. In the special cases where all the marginal effects on the actors' parts of the revenue following for a marginal increase in efforts dominate the effects on expected accident losses – i.e. the signs of U_t, π_e, U_{et} and π_{et} are all positive – it is seen from Tables 1 and 2 that the leader-follower solutions mean higher accident risks than in the simultaneous case. In such particular cases, where the efforts are strategic complements, and the driver and the company have interests in high effort by the opponent, the leader-follower games are not preferable seen from a traffic safety point of view, see Fig. 1. However, if U_t and π_e are negative and U_{et} and π_{et} are positive, such strategic complement cases induce the actors to make less intensive efforts in the leader-follower cases than the simultaneous case. As the marginal effects on expected losses dominate the effects on the portions of net revenue kept by the actors, they prefer low levels of effort by the opponent. The leader then chooses a low level of effort in order to stimulate the follower to do the same, resulting in relatively low accident probabilities, see Fig. 2.

In the case where the actors' effects on accident risks dominate the effects on their shares of the net revenue for all functions – i.e. the sign of U_t, π_e, U_{et} and π_{et} are all negative – we have cases where the efforts are strategic substitutes. Then the leaders in the two different games would choose a relatively high effort in order to force the follower to choose a low effort, and the consequence for accident risk is inconclusive compared with the simultaneous case, see Fig. 3. If U_t and π_e are positive and U_{et} and π_{et} are negative, we still have cases where the efforts are strategic substitutes. Now the leader would choose a relatively low effort level in order to stimulate the follower to choose a relatively high level of effort, implying that it is ambiguous whether the accident risks become lower or higher than in the simultaneous case, see Fig. 4.

However, by combining the information in Tables 1 and 2 it is possible to identify two cases when the efforts are strategic complements where the accident risks for a specific leader-follower game become low compared with the other games.

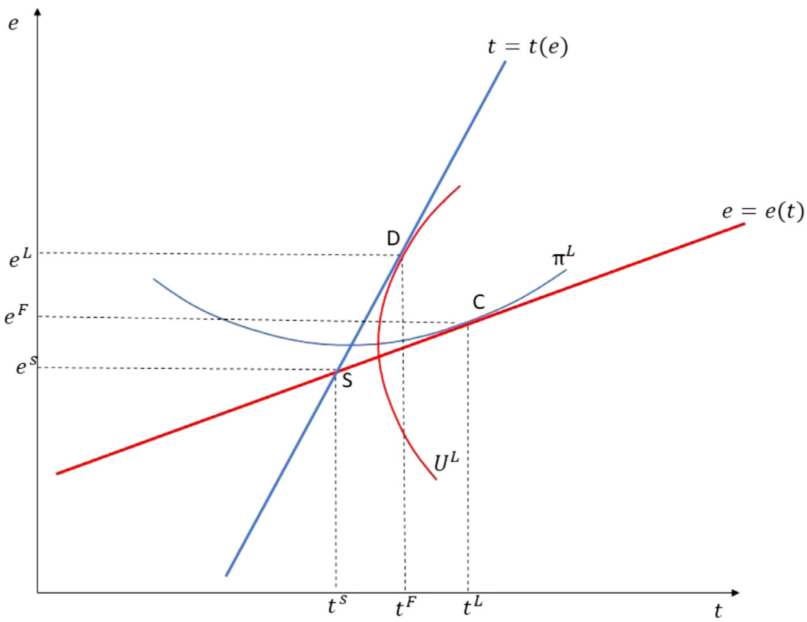

Fig. 1. An illustration of the case where $U_{et} > 0$, $\pi_{et} > 0$, $U_t > 0$ and $\pi_e > 0$.

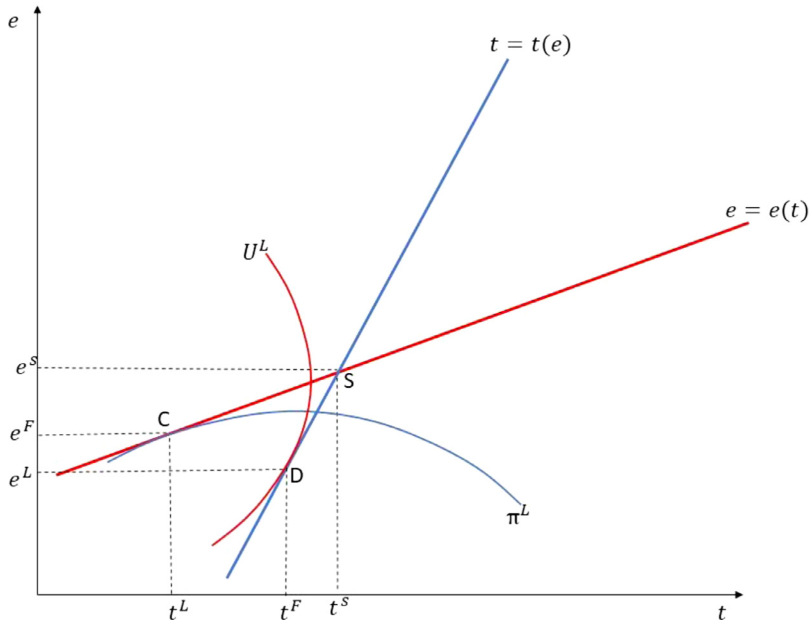

Fig. 2. An illustration of the case where $U_{et} > 0$, $\pi_{et} > 0$, $U_t < 0$ and $\pi_e < 0$.

Given that $U_{et} > 0$ and $\pi_{et} > 0$, and $\pi_e < 0$ and $U_t > 0$ hold, it is seen from Tables 1 and 2 that $t^L < t^S < t^F$ and $e^F < e^S < e^L$. This means that we now have $p^{LF} < p^S < p^{FL}$, implying that the game where the company is moving first, induces the lowest accident risk compared with the other games. In this game the company has an interest in reducing the effort of the driver, and, as the efforts are strategic complements, the company as the leader chooses a relatively low input, resulting in a low effort from the driver. This gives a relatively low accident risk. For the driver, it is the opposite. Her utility is increasing in the company's effort in this case, and if she became the leader, she would choose a high effort. Since the efforts are strategic complements, the company would answer by choosing a high level of effort, resulting in relatively high accident risks, see also Fig. 5. The other case where we find an unambiguous ranking of accident probabilities is similar. Given that $U_{et} > 0$ and $\pi_{et} > 0$, and $\pi_e > 0$ and $U_t < 0$ hold, the rankings of efforts following from Tables 1 and 2 become $t^F < t^S < t^L$ and $e^L < e^S < e^F$. These rankings give the opposite conclusion, i.e. $p^{FL} < p^S < p^{LF}$, implying that in this case it is preferable, from a traffic safety approach, that the driver should be the leader and the company should be the follower. Now the driver,

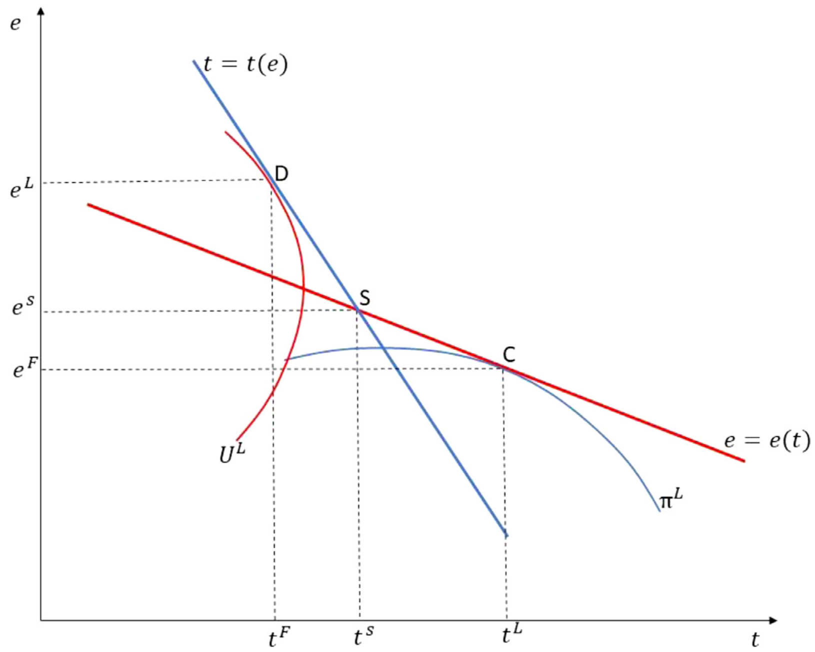

Fig. 3. An illustration of the case where $U_{et} < 0$, $\pi_{et} < 0$, $U_t < 0$ and $\pi_e < 0$.

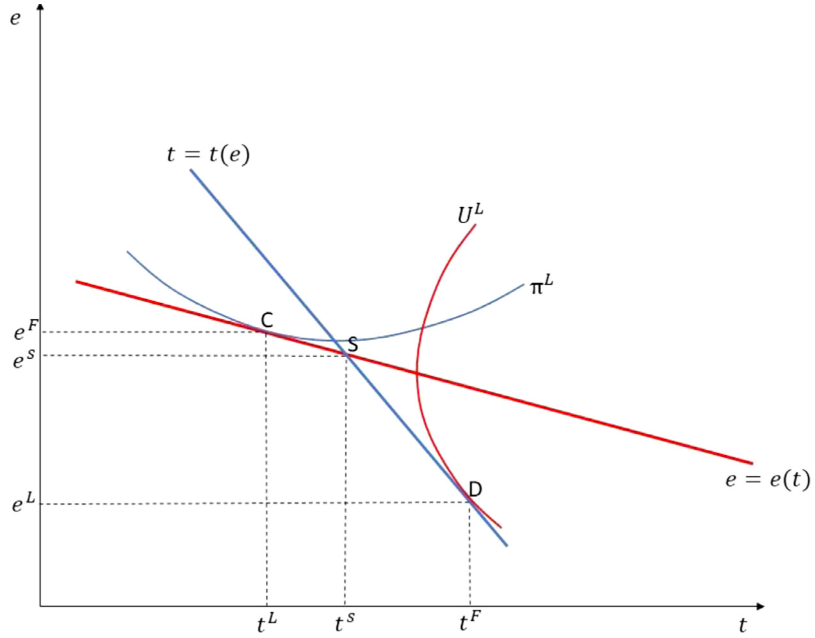

Fig. 4. An illustration of the case where $U_{et} < 0$, $\pi_{et} < 0$, $U_t > 0$ and $\pi_e > 0$.

by choosing a relatively low effort first, induces the company to follow up by inputting a relatively low effort, altogether implying a relatively low accident probability. If the company chooses first, its choice is a relatively high effort in order to prompt the driver to choose a relatively high effort, meaning a relatively high accident probability. This case is illustrated in Fig. 6.[9]

[9] By combining the information in Tables 1 and 2, it follows that when $U_t > 0$, $U_{et} \langle 0, \pi_e \rangle 0$ and $\pi_{et} < 0$ are satisfied, the rankings $t^L < t^s < t^F$ and $e^L < e^s < e^F$ hold, (see Fig. 4), and when $U_t < 0$, $U_{et} < 0$, $\pi_e < 0$ and $\pi_{et} < 0$ hold, the rankings $t^F < t^s < t^L$ and $e^F < e^s < e^L$ hold, (see Fig. 3). Even though in these two cases, additionally to the cases identified above, we are able to rank the efforts, it is not possible to rank the accident risks following from these two cases.

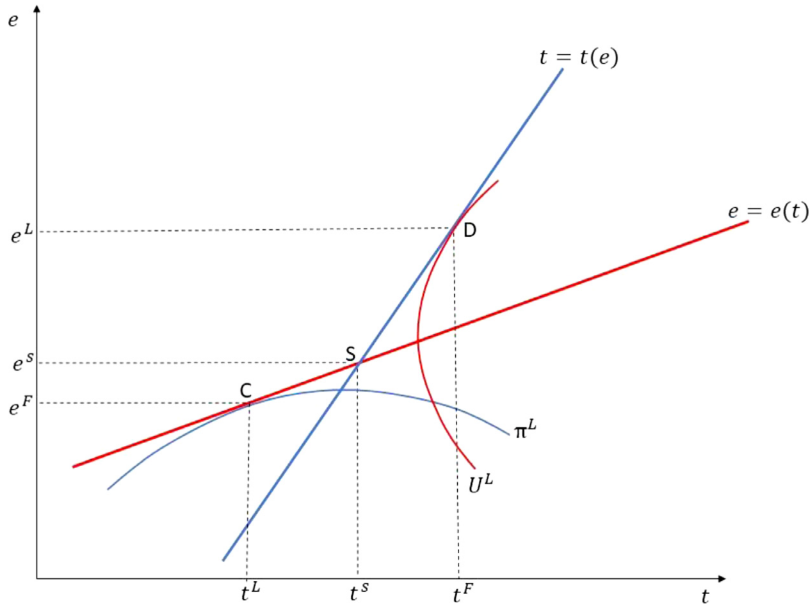

Fig. 5. An illustration of the case where $U_{et} > 0,\ \pi_{et} > 0,\ U_t > 0$ and $\pi_e < 0$.

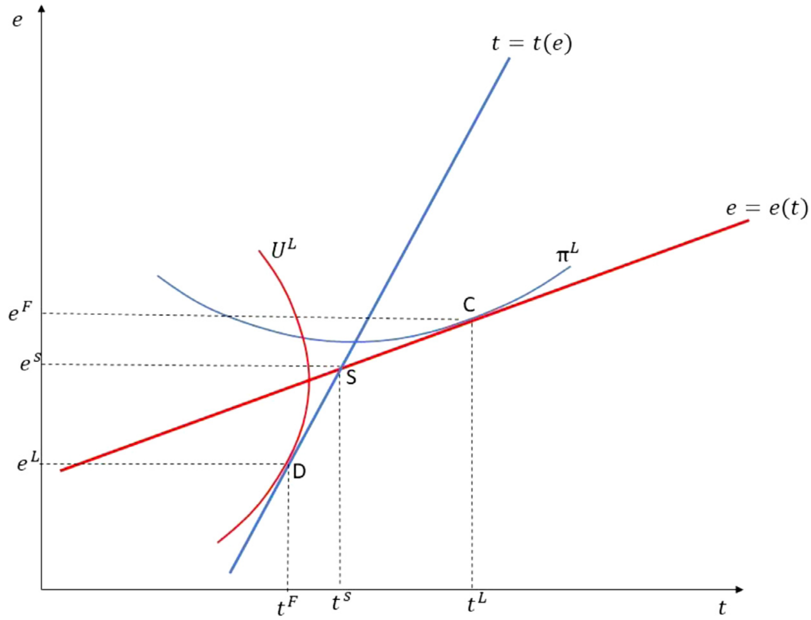

Fig. 6. An illustration of the case where $U_{et} > 0,\ \pi_{et} > 0,\ U_t < 0$ and $\pi_e > 0$.

Result 4.

a) In the cases where the company is the leader and the efforts are strategic complements, the simultaneous game gives higher accident risk than the leader-follower case if $\pi_e < 0$. When $\pi_e > 0$ and we are in the strategic complement case, the simultaneous game means lower accident risk than when the company is the leader.
b) In cases where the driver is the leader and the efforts are strategic complements, the simultaneous game gives higher accident risk than the leader-follower game if $U_t < 0$. When $U_t > 0$ and the efforts are strategic complements, the simultaneous game gives lower accident risks than the leader-follower game.
c) If the efforts are strategic complements, seen both from the driver and the company, and $\pi_e < 0$ and $U_t > 0$, the lowest accident risks will be realized if the company is the leader. When $\pi_e > 0$ and $U_t < 0$ and the efforts still are strategic complements for both parties, the driver as the leader will give the lowest accident risk. In all cases

where we have efforts as strategic substitutes, either when the company or the driver leads, it is ambiguous whether the simultaneous game gives higher or lower accident risks than the leader-follower games, and it is ambiguous which leader-follower games give the lowest accident risk.

As commented on above, normally the context will decide which of the three proposed games that will be played. However, it is possible to compare the actors' outcomes from these games and see which games would be preferred by the driver and the company respectively. In similar games in industrial organization, for instance, such discussions are often conducted by identifying first or second mover advantages, i.e. whether the transport company and/or the driver would prefer to be the first or second mover, see for instance Gal-Or (1985) and Pedersen (2003). For instance, if both players have a first mover advantage, it might be a race to become the leader which in sum leads to simultaneous moves. On the other hand, if both players have a second mover advantage, it might happen that both actors adopt an awaiting behavior, also implying that we may end up in simultaneous moves. It might also be possible that one of them has a first mover advantage and the other has a second mover advantage, and they both agree upon playing the particular leader-follower game they both prefer. However, as we have been most interested in using the different games here just to reveal the strategic interdependency between the actors' efforts and the influence this has on accident risks, we do not pursue the search for first and second mover advantages in our model.

We have not discussed the possibility that we might experience situations where there are multiple equilibria. For instance, a sufficient condition for having one and only one equilibrium in the simultaneous case is that the reaction functions, defined in (8) and (10), have only one crossing point, see for instance the Figs. 1–6. Generally, if one of the reaction functions are both decreasing and increasing for different values, or shifts from being concave to convex, it might happen that a simultaneous game has several equilibria. However, we do not pursue these reasoning here.

4. The optimal linear pay contract

Using a traditional principal-agent model, where we consider the company as the principal and the driver as the agent, it is possible to deduce an optimal linear pay contract, given the expected profit function in (1) and the expected utility function in (3). The principal-agent framework is a kind of non-simultaneous game, where the transport company as the leader, in addition to choosing its effort, decides the parameters in the wage contract, while the driver, after observing the wage contract and the company's effort, chooses her effort. So far we have considered a and b in relation (2) as exogenous parameters. A presumption in the principal-agent models is that the agent's (driver's) effort is a variable that is either unobservable for the principal or that the actual amount of effort chosen by the agent is impossible to verify. This implies that the pay for performance could not be directly dependent on the value of e. Most commonly, it is supposed that the production is affected by a stochastic variable in addition to effort, and that the realization of the stochastic variable is unobserved by the principal, see for instance Holmstrom (1979). This means that it is impossible for the principal to know whether a bad outcome is a result of shirking by the agent or unlucky events. In our model, where the net revenue is simply a function of e and t, it would be possible for the principal to calculate e, knowing R and t. However, we presume that e is unverifiable and, hence, is impossible to use in designing the wage contract. More generally, the difficulty in separating the effects of other variable factors is the inherent difficulty of contract design problems. Such effects might stem from unobservable actions made by the driver or other incidents on the road or elsewhere which affects the production and the traffic safety.

Moreover, in principal-agent models, it is usual to formulate a binding participation constraint for the agent, ensuring that she will at least obtain the same expected utility as she could have obtained externally. Let U^0 be the value of the expected utility in the outside option, implying that the wage contract has to fulfill the inequality

$$U \geq U^0 \tag{12}$$

In addition to securing participation from the driver, the principal (transport company) maximizes its expected profit with regard to t and the variables a and b define the wage contract – meaning that the company knows that the driver, after observing the wage contract, will maximize her expected utility. The driver's optimal behavior is defined by the first equation in (7) above. In this case, implicitly this equation defines e as a function of t, b and a. We already know from (8) how the driver reacts to different values of t. In order to find out how the driver reacts to different values of a and b, we differentiate the first equation in (7) and obtain

$$\frac{de}{da} = 0 \text{ and } \frac{de}{db} = -\frac{R_e}{U_{ee}} = -\frac{R_e}{bR_{ee} - g_{ee} - p_{ee}L^D} > 0 \tag{13}$$

From (13) it follows that the driver's effort is independent of the fixed payment a, and increases as the payment per net revenue, b, becomes higher. This means that we can consider e as a function of t and b, i.e. $e = e(t, b)$.

It will never be optimal for the transport company to pay more than necessary to keep the driver engaged. Hence, the participation constraint in (12) will, in optimum, hold as an equality. Inserting (2) and (3) in (12), interpreted as an equality, gives the fixed amount of payment a, defined by

$$a = U^0 - bR[t, e(t, b)] + g[e(t, b)] + p[t, e(t, b)]L^D \tag{14}$$

This value of a ensures that the driver wants to do the task. Now, in order to find the optimal values of b and t, we insert (2) and (14) in (1), remembering that the driver's effort must satisfy $e = e(t, b)$. The 1.order conditions for maximum expected profit can then be written as

$$\frac{d\pi}{db} = \left[R_e - g_e - p_e\left(L^C + L^D\right)\right]\frac{de}{db} = 0 \tag{15}$$

and

$$\frac{d\pi}{dt} = R_t - p_t\left(L^C + L^D\right) + \left[R_e - g_e - p_e(L^C + L^D\right]\frac{de}{dt} = 0 \tag{16}$$

The first equation in (7) and the Eqs. (14), (15) and (16) define the optimal values of *a, b, e* and *t*. From (13), we know that $\frac{de}{db} > 0$, which from (15) implies that $R_e - g_e - p_e(L^C + L^D) = 0$. This implies that the driver's effort, for the optimal contract, is decided when marginal net revenue minus the marginal disutility for the driver is equal to the expected marginal increase in accident losses for both actors. This means that the optimal pay for performance contract internalizes all relevant effects following from a marginal increase in the driver's effort. Using this result from (15) in (16), it is seen that the third term in this expression is zero, regardless of the sign of $\frac{de}{dt}$. This means that $R_t - p_t(L^C + L^D) = 0$ must be satisfied for the optimal contract. Then it is also seen that all relevant marginal effects on the net revenue, following from the company's effort and expected accident losses, are internalized when practicing the optimal contract. Combining this finding with the first equation in (7), describing the driver's optimal behavior, means that we use (15) to deduce the optimal value of b, i.e.

$$b = 1 - \frac{p_e L^C}{R_e} \tag{17}$$

The optimal contract is characterized by a payment that is partly dependent on production performance, i.e. $0 < b = 1 - \frac{p_e L^C}{R_e} < 1$. The first inequality follows because $R_e - p_e L^C = g_e + p_e L^D > 0$, i.e. $R_e > p_e L^C$. The second inequality follows from the assumptions made in 1b) and the presumption that there exists a loss for the company if an accident occurs. It is also seen from ((17) that the power of incentives in the optimal contract, i.e. the size of b, depends on the fraction between the marginal impact the driver's effort has on accident costs through higher risk for an accident, $p_e L^C$ and the positive marginal effect the driver's effort has on net revenue, R_e. The higher the values of p_e and L^C, and the lower the values of R_e, the lower the optimal b is. This implies that the optimal contract has less powerful incentives for the driver the more risk sensitive relative to production sensitive the company is. The optimal contract balances the company's risk and production sensitivities with regards to the driver's effort.

Another interesting point is that if the pay contract adopted is the optimal one, it is possible calculate how the company's expected profit changes with regard to e. Inserting (17) in the first equation in (6), it follows that $\pi_e = 0$. From the discussion concerning Tables 1 and 2 above, we then know that all games give the same effort values. This implies that the accident probabilities are the same for all games when the optimal contract is used, i.e. $p^S = p^{LF} = p^{FL}$. In line with this reasoning, we see that if b is lower than the optimal one, $\pi_e = (1 - b)R_e - p_e L^C > 0$, and if the company is the leader, we know that the relevant outcomes are in the first line in Table 1. This means that if b is below the optimal one, the effects on the company's share of the net revenue are higher than the effect on expected accident losses that follow from a marginal increase in the driver's effort. Analogously, when b in the wage contract is higher than the optimal one, $\pi_e = (1 - b)R_e - p_e L^C < 0$, the possible outcomes are in the third line in Table 1. Then the effect on the company's expected losses from any marginal increase in the driver's effort dominates the effect on its share of the revenue. However, we do not know the sign of U_{et} defining whether the efforts are strategic complements, independent or substitutes even though we easily see that the U_{et} becomes higher the higher level of b. This means that we do not generally know which columns in Table 1 that would be relevant in our case.

However, let us follow this reasoning a bit further. U_t is increasing in the level of b. Let us suppose that b is above the b in the optimal contract. Then $\pi_e < 0$. If we additionally suppose that $U_t < 0$, that can be a reasonable assumption as b is higher than the optimal one. If the efforts are strategic complements for both actors, then we have the particular case where $p^{LF} < p^S < p^{FL}$. This means that even when b is relatively high, giving the driver high effort incentives, a leader-follower game where the company moves first may produce relatively low accident risk. This illustrates that even if the degree of pay for performance is higher than optimal, the realized efforts and accident probability might be relatively low.

In the simplest principal-agent models, where both actors are risk neutral, as in our model, one normally finds that all incentives should be given to the agent, i.e. $b = 1$, see for instance Stiglitz (1974), Holmstrom (1979), Bergland (1995) and Grepperud and Pedersen (2006).[10] However, in our model, the risk consequences are initially divided between the company and the driver, and the pay for performance contract has to internalize these divided accident risks. This leads to a less powered contract than is often found in the principal-agent literature.[11]

[10] In Stiglitz (1974), Holmstrom (1979) and Bergland (1995) it is seen that in the case of a risk averse agent, it is optimal for the principal to provide a wage contract characterized by b above 0 and below 1 to balance the need to secure efficiency and find an appropriate way to share the common risks among the actors. In Grepperud and Pedersen (2006), however, a linear contract with a b lower than 1 becomes a way to balance the need for efficiency and possible crowding effects following from using a performance-based wage contract.

[11] Perhaps less realistic than considering the company as the principal and the driver as the agent, an alternative is to formulate a model where the driver is the principal and the company is the agent. However, the model reasoning would be analogous, and the properties of the optimal contract are

Result 5. The driver will increase her effort as the power, b, in the wage contract becomes higher. The optimal b is between 0 and 1. The optimal value of b becomes higher the less impact a marginal increase in the driver's effort has on accident risk, the lower the company's loss is if an accident occurs, and the higher impact a marginal increase in the driver's effort has on net revenue. Practicing the optimal pay for performance contract means that the simultaneous game and the two leader-follower games give the same efforts, implying identical accident risk.

5. Social welfare

An important finding in the traditional principal-agent models is that the optimal wage contract in the absence of risk aversion, defined by $b = 1$, also induces the maximum social welfare. If we maximize the sum of the expected profit and the expected utility defined in (1) and (3), we obtain the following conditions

$$R_t - p_t\left(L^C + L^D\right) = 0 \text{ and } R_e - g_e - p_e\left(L^C + L^D\right) = 0 \tag{18}$$

which are analogous equations to the conditions for deciding the effort levels in the principal-agent model when using the optimal wage contract, see Eqs. (15) and (16). This also means that in our model an optimal contract would secure the maximum sum of expected profit and utility for the two actors. However, even though the optimal contract internalizes the parties' expected gains and losses, road transportation has possible positive and negative external effects which the parties, without public regulation, do not have any incentive to take into account when determining their efforts. If we restrict ourselves to discussing the parties' behavior in a traffic safety context, accidents normally have negative consequences also for 'third persons', such as passengers, other road users and the transport company's customers. Suppose now that such losses could be termed L^E and that we can formulate the welfare, W, from the transport activity as

$$W = \pi + U - p(t, e)L^E \tag{19}$$

Then the welfare optimal solution is given by

$$W_t = R_t - p_t\left(L^C + L^D + L^E\right) = 0 \text{ and } W_e = R_e - g_e - p_e\left(L^C + L^D + L^E\right) = 0 \tag{20}$$

By comparing (18) with (20) it is easily seen that the transport company's and the driver's private incentives generate excessively high efforts in production, neglecting the negative influences high effort levels have on risks and accident costs for other groups. Hence, even when an optimal contract is practiced between the company and the driver, there is a rationale for indirect public regulations, for instance taxes, aiming to internalize such third party costs. Or for direct regulations as speed limits, driving time restrictions, technical claims on vehicle equipment, injunctions on vehicle maintenance and regulations of maximum working hours. As analyses concerning optimal public policies in order to secure social welfare – in the context of negative externalities concerning accident risks on roads – have been carried out elsewhere, see for instance the references on traffic safety research in the introduction, we do not discuss this issue here.

Result 6. The optimal contract perfectly internalizes the actors' expected gains and costs. However, most reasonable road transportation implies negative externalities concerning traffic safety for other persons and institutions, implying a need for public regulations of professional road transportation in order to secure optimal social welfare.

6. Concluding remarks

We have formulated a game theoretical model where we focus on the strategic interaction between a transport company's management and a driver. Both the company's management and the driver choose efforts that affect production efficiency and traffic safety. If an accident occurs, both the company and the driver face possible losses. We started the analysis by discussing the actors' behavior for an exogenous pay for performance contract where both the simultaneous and the two leader-follower solutions are deduced and compared. We have seen that the strategic interactions between the company's and the driver's efforts can be characterized either as strategic complements or strategic substitutes. In the cases of strategic complements (substitutes), an increase in effort from the leader means that the opponent will increase (decrease) its effort. Additionally, the choices of efforts are dependent on the signs of expected marginal profit with regard to the driver's effort, and the expected marginal utility with regard to the company's effort. If these marginal effects are positive (negative), the actors prefer higher to lower (lower to higher) effort from the opponent. Generally, it is not possible to conclude whether the two leader-follower solutions induce higher or lower accident risks than the simultaneous case. However, in cases where the efforts are strategic complements, and the expected utility and expected profit are growing in the opponent's effort, the leader-follower games induce higher accident risks than in the simultaneous case. Moreover, the

that the net revenue from production will be shared among the actors. In such a case it can be shown that $0 < \beta = \frac{p_t L^D}{R_t} = \frac{L^D}{L^C + L^D} < 1$ and $U_t = 0$, where β is the payment per revenue unit to the driver in this model. β in this contract will internalize the driver's gains and costs onto the company's decision when it chooses its effort, and, hence, the value of β is slightly different from the b in our model. It is seen that as the company's loss from an accident becomes lower, and the driver's loss from an accident increases, the higher the optimal β is. In our model, the company sets the value of a such that the driver will only obtain the outside option level U^0, meaning that the company obtains all the gains from the contract. However, in this alternative model the driver will use a similar reasoning, setting the value of a fixed term in the contract such that the company's expected profit is only equal to a minimum acceptable level of expected profit, and cash in all the gains from the optimal contract.

strategic complement cases produce lower accident risks if the expected utility and profit are decreasing in the opponent's effort.

When turning our attention to the optimal wage contract, considering the company as the principal and the driver as the agent, we have seen that it is optimal for the company to provide the driver with a pay for performance contract. This contract is characterized by sharing the net revenue with the driver. The driver's share becomes higher the higher impact a marginal increase in her effort has on the net revenue, the lower impact a marginal increase in her effort has on accident risks, and the lower the company's loss is if an accident occurs. In contrast to the simplest principal-agent model where both actors are risk neutral, it is not optimal in our model to use a perfectly flexible contract. This stems from the need for the transport company to use the pay contract to internalize the expected costs that the company faces if an accident occurs.

It also follows that when practicing the optimal contract, the simultaneous and the lead-follower games all give the same solutions, and that this outcome is in accordance with the efforts that maximize the sum of expected profit and utility. For a less powered contract than the optimal one, the company's expected profit increases as the driver steps up her effort. In the case of strategic complements, the company as a leader could increase its effort to induce the driver to step up her effort. In the case of strategic substitutes, however, the leading company reduces its effort in order to induce the driver to increase her effort. For higher powered contracts than the optimal one, the company's profit reduces as the driver's effort increases. In the case of strategic complements, the company as the leader will reduce its effort to give the driver incentives to decrease her effort. In the case of substitutes, the leading company will increase its effort to induce the driver to reduce her effort. If the wage contract stems from centralized negotiations between the drivers' union and the road transport operators' organization, such a contract most likely will deviate from the optimal contract a specific company and the driver will have chosen, in one way or another.

Even if the optimal contract is used, one that perfectly internalizes the expected gains and costs for the transport company and the driver, it still does not account for the negative externalities accidents might have on other individuals using the roads. In order to secure overall social welfare, it is still necessary for a public authority, either by direct or indirect means, to regulate road transportation practices – for instance by speed limits, driving time regulation, vehicle standards, licencies or taxes.

A main point in our analyses has been to identify situations where practicing pay for performance for drivers leads to relatively high accident risks and cases where the opposite is true. Hence, our model discussions nuance some of the referred literature in the introduction claiming that drivers' eagerness to make money unilaterally would mean high accident risks. Another important point has been to show that an optimal contract between a driver and a transport company means that the actors should share the expected gains from the production, i.e. $0 < b < 1$. This stems from the fact that both the company and the driver influence accident risks and income, and have individual losses when accidents occur. Additionally, we have seen that the more risk sensitive relative to production sensitive the company is, the less powered should the wage contract be.

Our model and analyses should be considered as a conceptual and theoretical contribution to the discussion on efficiency and traffic safety. In addition to highlighting that high effort levels, chosen by managers and drivers in transport operations, induce accident risks on the roads, we emphasize that high efforts also mean higher production and possible higher income for transport companies and drivers. Hence, when considering marginal changes in efforts, both the transport managers and the drivers consider the possible expected gains and costs accruing to them. In conducting our analyses, we have made many simplifying assumptions usually applied in game theoretical models and principal-agent analyses.

Firstly, the production technology for the sake of simplicity is described by only two inputs; one controlled and adjusted by the managers in the transport company and one controlled and adjusted by the drivers. In reality, both the mangers and the drivers take many decisions affecting both the revenue and the risks for accidents. Additionally, the wage function might be more complex and dependent on more variables than the net revenue. However, on the conceptual and theoretical level, we believe that the chosen model reveals the main strategic aspects going on between the company and the driver. By focusing on the simultaneous case and the two possible leader-follower games, and by comparing the outcomes of these games, we have been able to characterize important factors crucial for the strategic interaction and for accident risk outcomes. However, our discussion is limited to a one period model, where we study the strategic interactions and the design of an optimal payment contract within this period. An extension for a further study would be to make the model dynamic by including more than one period, and where the actors' former behavior and presence or absence of accidents might be considered to be a part of the wage contract design.

Secondly, we have limited ourselves to analyzing contracts within a road transportation company, between the management and its drivers. The transport company, however, supplies transport services to customers who may have demanding claims in their contracts with the transport operator which affect both the company's income possibilities and expected accident losses. In future research, it will be interesting, from a theoretical point of view, to focus on such external contracts. If these contracts have a kind of pay for performance element, they may influence efficiency and accident risks in a similar fashion to the internal contracts we have been discussing. Another relevant endeavour for future research on pay for performance in professional road transportation is to do empirical studies where one focuses on three elements – economic efficiency for the companies, the behavior of the drivers and the traffic safety consequences of practicing different kinds of pay contracts. Similar empirical studies are also interesting for external contracts. However, in order to do such studies, more specified and precise action variables for the actors have to be included. Our theoretical analyses of possible strategic interactions between a transport company and its drivers, and the focus on pay for performance, may serve as relevant background for future studies concerning contracts in road transportation.

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Supplementary materials

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