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ECONOMIC REWARD AND ON-ROAD PERFORMANCE OF LONG DISTANCE TRUCKING: AN ECONOMETRIC ASSESSMENT

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ABSTRACT: This paper reports the results of an econometric analysis of the influences on economic reward and on-road behaviour of long distance truck drivers in Australia. Drawing on a 1990 survey of a sample of 800 truck drivers selected from owner drivers and employee drivers, we identify the important role that rates of pay and the payment method have on the propensity to speed. The richness of the data enables us to evaluate the endogenous linkage between speeding, the taking of pills, and the self-imposition of schedules, as well as identify industry practices which have desirable and undesirable impacts on the performance of drivers. The empirical findings corroborate anecdotal evidence on the issues which need action in the interests of minimising the negative externalities of an essentially efficient and safe industry.

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1. Background

In recent years there has been growing concern that the safety of our roads, particularly the national highways, has been deteriorating. This is purported to be partly related to the unsafe on-road behaviour of long distance truck drivers. In Australia, this view was influenced by the marked increase in fatal crashes involving semi-trailers in 1988 and by a particularly severe crash between a semi-trailer and a coach which claimed the lives of 20 people and injured 18 passengers in October 1989. In 1988, there were 151 fatalities in New South Wales resulting from crashes involving semi-trailers. This was twice the number in 1987. The high rate of fatalities continued in 1989 with 143 people killed in crashes involving semi-trailers.

The media attention given to crashes involving long distance heavy vehicles has helped create a negative image of the long distance truck driver and the trucking industry as a whole. The negative image of truck drivers has evolved with little, if any, questioning of the reasons behind that behaviour. We do not believe that it is reasonable to assume that all operators in the industry are irresponsible "cowboys", who spend long hours speeding along the highways without thought for their own or other road users' safety. Indeed, analysis of crash statistics shows that the incidence of heavy vehicle crashes relative to exposure on the road is very small and represents an impressive safety record (Hensher et al. 1991).

Theories and anecdotes about the causes of unsafe on-road behaviour of heavy vehicle drivers abound. But there is a dearth of *substantive* studies directed towards an enquiry into the causes of particular on-road behaviour and hence levels of exposure to risk of a crash. The study reported here evolved out of a concern that there is a lack of systematic scientific evidence, especially in relation to the links between the underlying economic structure of the industry and on-road performance (Savage 1989, Sweatman et al. 1990). Without better evidence, we run the risk of regulatory authorities proposing inappropriate strategies to modify the on-road behaviour of the long distance trucking industry in order to improve the safety of the road environment. Often "band-aid" policies are introduced in response to a particular incident receiving public attention. For example immediately following the October 1989 truck and coach crash on the Pacific Highway, the speed limit for heavy vehicles was reduced from 100 km per hour to 90 km per hour.

This study explores the possibility of links between the propensity of a driver to speed and the economic conditions in the industry in general and the driver's own particular economic operating environment. We concentrate on speed and fatigue as indicators of exposure to risk. These factors were found to be major contributors to crashes in a study of all heavy vehicle crashes in NSW in 1988 (Sweatman et al. 1990). Given that there are a number of complex inter-relationships which contribute to the ultimate on-road performance of truck drivers (Hensher and Battellino 1990), the separation of the major sources of influence can only satisfactorily be achieved by a formal quantitative investigation using suitable econometric techniques. The interactions between the major elements of the study are summarised schematically in Figure 1. The critical dimensions which require explanation are the economic rewards (annual income net of expenses), the overall number of hours of work required to return an acceptable income, the number of productive driving hours, the incidence of speeding, the extent of fines for speeding in particular and its links with economic return, the incidence of pill taking and self-imposition of schedules and its linkage with on-road performance with respect to sources of exposure to risk.

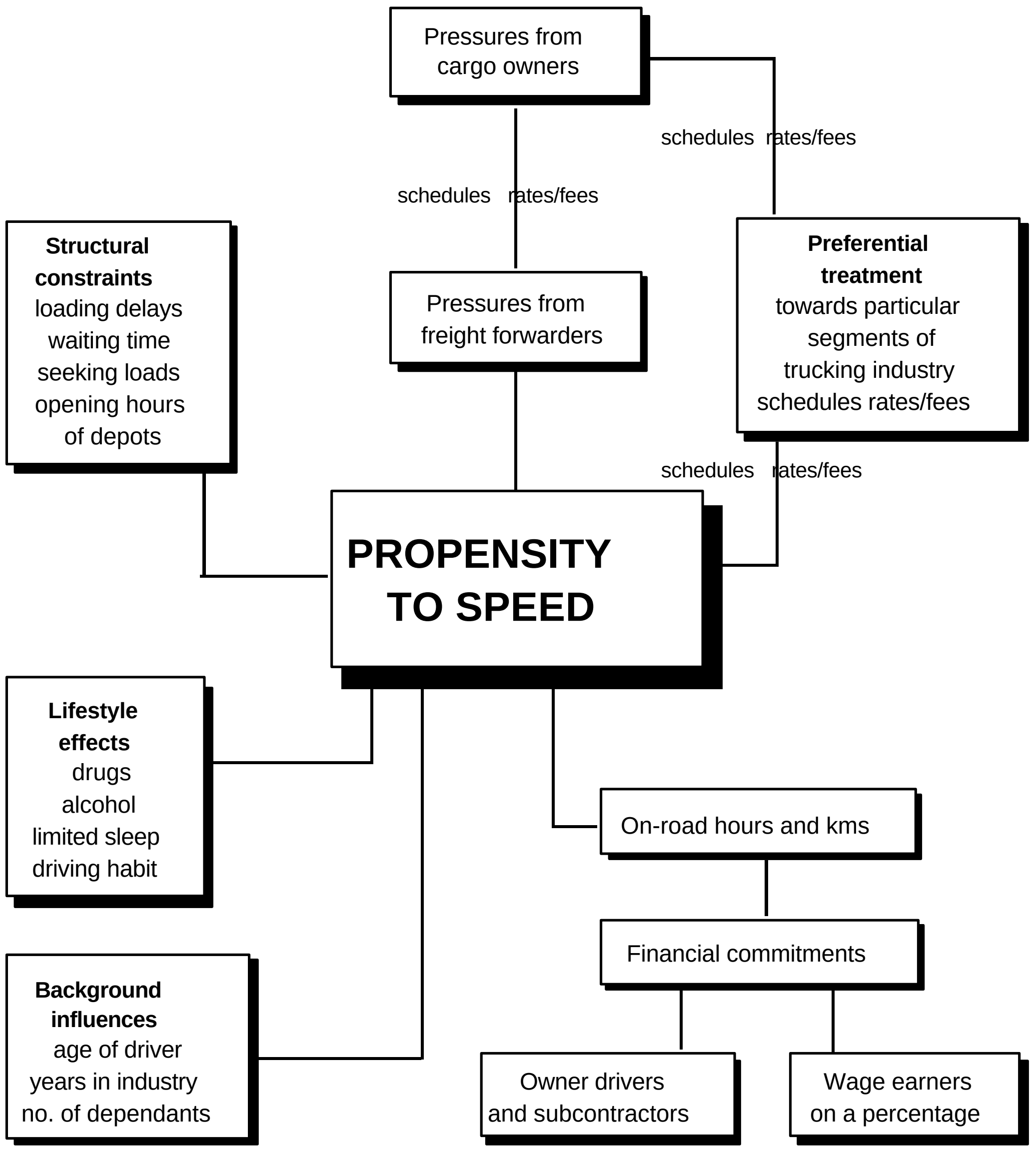
Data was collected from an indepth face to face interview of 800 long distance truck drivers throughout Australia. A key aspect of the survey was obtaining data on a recent trip undertaken by each driver. Descriptive analysis of the sample data is reported fully in Hensher et al. (1991) and summarised in Hensher et al. 1992 and the Appendix. The richness of the information from the survey available to draw on for the econometric analysis is summarised in Table 1.

The paper is organised as follows. The causal structures of the behavioural model systems associated with the annual economic reward profile and the trip-specific exposure to risk are presented, followed by the empirical results and interpretation for each of the model systems. A summary of the major findings is given in the conclusion.

2. The Causal Hypotheses

It is hypothesised that a truck driver is motivated by economic reward and seeks to obtain a return for his efforts through participation either as an owner driver or employee driver. The decision on whether to be an employee or to be self-employed is in part influenced by the opportunities for reward, the flexibility of lifestyle and the extent of a real choice (i.e. the availability of employment in the employee driver sector). Given the highly competitive "cut-throat" nature of the long distance trucking industry, drivers exhibit substantial variations in strategic behaviour in order to survive. The pressures on drivers come from freight forwarders, cargo owners, and the large number of operators competing for loads.

Figure 1 Major elements of the study



The lifestyle element of trucking, especially for owner drivers and small company employees, has reinforced the acceptability of working practices which in other industries would be regarded as totally unacceptable. Typically, many drivers spend considerable time waiting for an opportunity to secure a load, they rarely sleep at their "permanent residence", spend considerable hours in the cabin of their truck, and live on a "junk-food" diet (AUSTROADS 1991). Reliance on "stay-awake" pills is quite widespread (46% of sampled drivers take pills on some trips or all the time) in order to maintain very long working hours, typically averaging 100 hours per week (Hensher et al. 1992). Self-imposed schedules which may encourage excess speed are often the outcome of the pressures on truckies, especially owner drivers.

Table 1 Potential sources of influence on economic reward and the propensity to speed

1. On-Road Profile
- Total kilometres (TS)
- Total time (TS)
- Total number of legs (TS)
- Incidence of drive time per leg (TS) *
- Variance of drive time incidence per leg (TS) *
- Speed profile of trip (TS) *
- Average speed per leg (TS) *
- Speed variance across legs (TS) *
- No. of stops involving particular activities (sleep, rest, eat, etc.) (TS) *

2. Trip Timing
- Depart during the weekend (TS) *
- Depart early morning (TS)
- Depart during the day (TS)
- Depart during the evening (TS) *
- No. and % of hours driving in the dark (TS) *

3. Pressures on Performance
- External schedule constraints (TS) *
- Self-imposed schedules (TS) *
- Loan repayments *

4. The Road Environment
- Specific-roads (quality proxy) (TS)
- Direction of travel on a specific road (TS)
- Major origin-destination pairs (TS) *
- Frequency of trips on major routes *

5. Vehicle Characteristics
- Body type (rigid, articulated) (TS) *
- Age (TS)
- Weight (TS) *

6. Cargo Characteristics
- Weight (TS)
- General cargo (TS)
- Perishable cargo (TS) *
- Express freight (TS)
- Specialised cargo (TS)

7. Safety and Security Control
- Speed limiter installed (TS)
- Tachograph on board (TS)
- Incidence of fines (speeding, log book, truck defaults, overloading) *

8. Driver Background
- Age *
- Number of dependants (children)
- Prior occupation *
- Undertaken a training course
- Number of crashes in previous 2 years

9. Industry Experience
- Years driving
- Annual kilometres
- Annual working hours *
- Annual driving hours *
- Number of trucks possessed *

10. Lifestyle Attributes
- Reliance on pills (always, some trips) *
- Means of maintaining alertness en route
- Activities in 8 hours prior to departure (TS) *

11. Preferential Treatment
- Regular contracts (for all, some, no loads) *
- Access to load (TS)
- Backload provisions *

12. Sub-Industry Status
- Employee driver (small, medium, large co.) *
- Owner driver fleet owner *
- Owner driver prime contractor *
- Owner driver independent sub-contractor *
- Independent owner driver *

13. Economic Reward Determination
- Owner driver (c/km) (TS) *
- Employee driver - fixed salary, % of truck earnings, per trip *

14. Structural Constraints
- Backload available (TS) *
- Unloading time (TS)
- Waiting to unload (TS)
- Time to usually secure loads *

15. Financial Status
- Annual truck-related income
- Annual truck-related expenses (OD) *
- Non-truck related income
- Truck financial commitments *

16. Other Dimensions
- State location of base *

* = included in the model system
TS = data specific to one trip

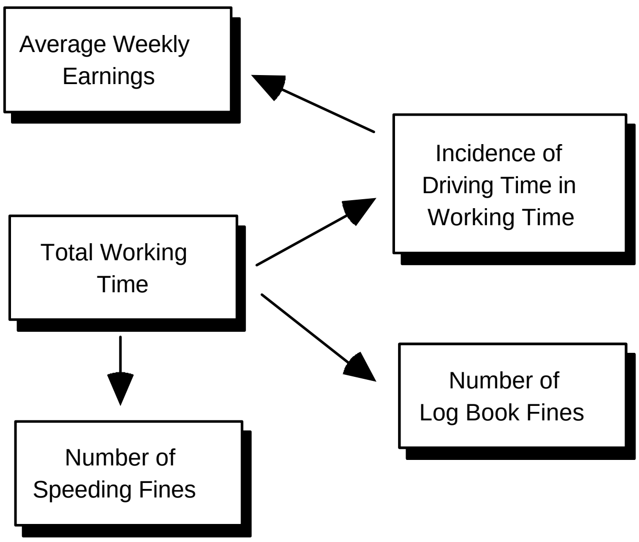
The challenge in this study is to establish the links between good and bad practice, positive and negative incentives and the two key concerns of economic reward and on-road performance in the context of exposure to risk. The evidence can be used to establish some guidelines for changes to be encouraged in the industry which will improve the working environment in a way that both enhances the economic rewards of drivers and their on-road performance.

With these objectives in mind, two causal structures (summarised in Figure 2) are proposed:

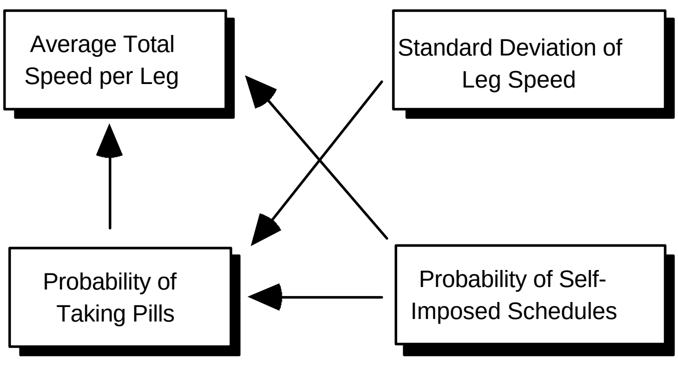
(i) Model system I - MSI: the annual economic reward profile, and
(ii) Model system II - MSII: the trip-specific exposure to risk.

Figure 2 The causal structure of the two model systems

Model system I: Annual economic reward profile



Model system II: Trip-specific exposure to risk



MSI hypothesises that total working hours are influenced by a number of *exogenous* factors representing the sixteen generic categories of potential influences (Table 1). These factors are used to explain behaviour. Total working hours determine, with other exogenous variables, the proportion of work hours that involve time behind the wheel; and the incidence of wheel hours together with a number of exogenous effects, determine the average weekly earnings of drivers (net of truck-related expenses for owner drivers).

MSII hypothesises that on-road performance as measured by average speed per trip leg and/or the standard deviation of the average trip leg speeds is influenced by a number of exogenous variables and two *endogenous* effects - the propensity to take pills and the propensity to adopt self-imposed schedules. Schedules imposed by a company or freight forwarder are exogenously determined and hence are treated as given constraints on behaviour. This influence is hypothesised to operate in one of two possible ways: (i) the propensity to have a self-imposed schedule influences the propensity to use pills which in turn has an effect on the average speed per leg (and the standard deviation across legs) and (ii) the propensity to take pills and to self-impose a schedule jointly influence the on-road speed profile.

One of the important features of the study is the link between on-road performance and economic reward. The link is achieved via information on the actual rate received for each trip. For owner drivers this represents money earned by the driver, however for an employee driver this represents the earnings of the employer. We were unable to identify the actual earnings for the trip attributable to an employee driver; our empirical analysis makes a distinction between the earnings of the owner driver and the earnings of the employer. This enables us to evaluate the role of the freight rate on on-road performance which in the case of an owner driver is also the economic reward. Since each trip's rate or fee is negotiated in a number of dimensions (per load, per tonne, per km) all trip rates were converted to an equivalent rate per kilometre.

Since 7% of owner drivers and 65% of employee drivers did not know the rates, the modelling presents two sets of empirical results: one for the full sample (791 trips excluding fleet operator owner drivers and a few unreliable observations) and one for the trips where the rates are known (410). The decision to present two sets of results was taken to preserve the richness of the full sample in respect of the role of variables other than trip rates. However given the importance of trip rates in providing the trip-specific link between overall economic reward and on-road performance, the smaller sample was analysed. The larger sample was used to identify the set of influences on on-road performance which were included in the reduced-sample model together with separate trip rate variables for owner drivers and employee drivers.

3. Model Specification

3.1 Model system I - Annual Economic Reward Profile

This model has five endogenous variables:

1. Average weekly earnings net of truck expenses (INCPWKN)
2. Incidence of driving time in total work hours (DRVHRS)
3. Total work hours (WORKHRS)
4. Number of speeding fines in the last 12 months (FINES)
5. Number of log book fines in the last 12 months (FINEL)

With WORKHRS and DRVHRS appearing on the right-hand side of four of the equations (Figure 2), a system of simultaneous equations is estimated using three stage least squares (3SLS) (Greene 1990).

3SLS recognises, and allows for, the non-independence of the error structures of each of the equations. The left-hand side (LHS) variable in a single equation is a function of a set of exogenous variables and a set of unobserved effects, the latter generically represented by the error or disturbance term. When the endogenous variable is introduced into a second equation as a right-hand side variable, it is likely that the error term of the first equation will be correlated with the error term of the second equation since they potentially measure a number of common influences on both endogenous variables. Failure to recognise this possibility and to allow for it can result in biased parameter estimates of the RHS variables. This becomes a source of misleading inference as to the role of RHS variables in explaining variations in the magnitude of the RHS variable.

3.2 Model system II - Trip-Specific Exposure to Risk

The endogenous variables in MSII are a mixture of continuous and discrete variables. Techniques such as OLS and 3SLS are not appropriate when a dependent variable is discrete (Hensher and Johnson 1981, Greene 1990). When an endogenous RHS variable is discrete, we need to consider the phenomenon of sample selection (or selectivity) which represents the idea of partial inference with respect to each sampled individual's behaviour. Think of the situation of a driver who is currently taking pills. We observe how this habit affects his driving speed. We do not observe how his driving speed is affected if he did not take pills. Conversely we observe the driving behaviour of a person not on pills, but not his behaviour if he were to take pills. Since the choice of taking pills is an endogenous choice (i.e. the individual chooses himself), the inability to observe each driver's behaviour in the absence/presence of pills given their current status means that we have potential sample selectivity bias (due to self-selection). Because we have a sub-sample of pill takers and a sub-sample of non-pill takers, we can combine the two samples and use the endogenous dummy variable PILLS together with an auxiliary regressor to test for the effect of any likely selectivity bias due to the absence of such information. If the non-pill takers have characteristics similar to the pill takers which influence their propensity to speed after allowing for sources of influence on the choice between taking or not taking pills, then we would expect to reject the hypothesis of selectivity bias.

Formally, we begin by assuming that the sample of pill taking and non-pill taking drivers are drawn from a **single** population of long distance drivers. For the *i*th driver, ($i = 1,...,d, ...D$), let y_i be the on-road measure of performance (average speed); z_i the pill taking variable (1 = takes pills, 0 = do not take pills); w_i the unobserved "lifestyle" and "pressures"; x_{1i} the exogenous vector of *k* background variables (including the constant); x_{2i} the exogenous vector of *m* background variables, where x_{1i} is a subset of x_{2i} ; and z^* is the unobserved continuous variable determining pill taking. The model system which recognises the relationships between these elements is:

(1) $$y_i = \omega_i + \alpha z_i + \varepsilon_{oi}$$

(2) $$\omega_i = x'_{1i} \beta_1 + \varepsilon_{1i}$$

(3) $$z_i = x'_{2i} \beta_2 + u_{2i}$$

(4) $$z_i = 1 \text{ if } z_i^* > 0$$
$$z_i = 0 \text{ if } z_i^* \leq 0$$

Substituting equation (2) into (1) gives equation (5):

(5) $$y_i = x'_{1i} \beta_1 + \alpha z_i + u_{1i}$$

where $u_{1i} = \varepsilon_{0i} + \varepsilon_{1i}$. It is assumed that u_{2i} is normally distributed and $E(u_{1i} | u_{2i})$ is a linear function of u_{2i} such that:

$$E(u_{1i}) = E(u_{2i}) = 0$$
$$var(u_{1i}) = \sigma_1^2$$
$$var(u_{2i}) = 1$$
$$cov(u_{1i}, u_{2i}) = \rho\sigma_1$$
$$cov(u_{1i}, u_{1j}) = cov(u_{1i}, u_{2j}) = 0 \text{ of } i \neq j$$

u_{2i} is constrained to have unit variance without any loss of generality. Let us now define $\theta = - x_{2i}' \beta_2$. Barnow et al. (1981) have shown that:

$$(6)\quad E(u_{2i} | \theta, z_i) = z_i f(\theta_i)/(1 - F(\theta_i)) - (1 - z_i) f(\theta_i)/F(\theta_i)$$

$$= h_i(\theta_i) \text{ or } h_i$$

where $f(.)$ and $F(.)$ define the standard normal density and the cumulative distribution functions. It follows that:

$$(7)\quad E(u_{1i} | \theta_i, z_i) = \rho\sigma_1 h_i$$

The application of OLS to equation (7) will produce unbiased estimates of α and β_1 only if $\rho\sigma_1 h_1 = 0$. This condition can be satisfied if one or more of the following requirements are met:

a. Equation (3) predicts pill taking choice without error ($u_{2i} = 0$ for all drivers).
b. Drivers are randomly assigned to pill taking and non-pill taking categories (i.e. $var(u_{1i}) \neq 0$, $var(u_{2i}) \neq 0$, $cov(\omega_i, z_i^*) = 0$ and thus $cov(u_{1i}, u_{2i}) = 0$).
c. Although lifestyle, industry pressures and pill taking choice are correlated in the driver population [$cov(\omega_i, z_i^*) \neq 0$], there is no correlation between lifestyle/industry pressures and pill taking choice after conditioning on observed X_2 [$cov(\omega_i, z_i^* | x_2) = cov(u_{1i}, u_{2i}) = 0$ for all drivers].

Requirement (a) is unlikely to be met. Requirements (b) and (c) need to be tested. We cannot impose the assumption that (b) or (c) is satisfied. Given the single-population assumption, if we can assume that the values of $ß_1$ are independent of pill taking choice, then consistent estimates of parameters can be derived as follows:

Implement a pill taking choice model of the binary probit form using maximum likelihood to obtain parameter estimates for $ß_2$:

$$\text{(8)} \quad \Pr[\ z_i = 1\ ] = F(\ x_{2i}^{\prime}\ \beta_2)$$

Given the estimator $ß_2$, calculate a parameter index

$$\text{(9)} \quad \hat{\theta}_i = -\ x_{2i}^{\prime}\ \hat{\beta}_2$$

and define the auxiliary or selectivity regressor:

$$\text{(10)} \quad \hat{h}_i = z_i\, f(\hat{\theta}_i)/(1 - F(\hat{\theta}_i)) - (1 - z_i)\, f(\hat{\theta}_i)/F(\hat{\theta}_i)$$

Then include this selectivity term in equation (5), denoting the unknown scaling or parameter of $\rho\sigma_1$ as c, to obtain the selectivity regression:

$$\text{(11)} \quad y_i = x_{1i}^{\prime}\ \beta_1 + \alpha z_i + c\,\hat{h}_i + \eta_i$$

The parameter estimates in (11) are consistent when OLS is used; however a correction is required to allow for heteroscedastic errors ω_i and η_i unless $\rho = 0$. The correction is implemented in this study to ensure that the standard errors of the OLS model are correct (Greene 1981).

The approach can be extended to more than one endogenous dummy variable and alternative assumptions on the distributions of the unobserved effects in the discrete choice model. In the current context we want to investigate pill consumption and self-imposed schedules, both being observed as discrete binary variates. However, there are two reasonable structural relationships between schedules and drugs:

(i) The first assumes that pill taking and the self-imposition of a schedule are joint (correlated) determinants of the propensity to speed. A bivariate probit model (using starting values from individual binary probit models) is estimated to produce two selectivity regressors.

(ii) The second assumes that the probability of pill taking is conditional on whether a driver has a self-imposed schedule, and that pill taking then directly influences the propensity to speed. A nested logit model is estimated. First the choice of a self-imposed schedule is modelled as a binary logit specification. The probability outcomes are used to construct an index which represents the *expected maximum utility* (EMU) associated with the self-imposition of a schedule conditioning the probability of pill taking. The pill taking logit model is then estimated with the EMU index included as a RHS variable. If the parameter estimate of EMU is not statistically significantly different from unity, then the choice of a self-imposed schedule and pill taking is a joint determination (Hensher 1986). The selectivity term derived from the pill taking model takes a different form to that in the first specification although it has the same interpretation. This arises because the unobserved effects in the logit model have an extreme value type I distribution.

To understand the logit approach as a representation of an alternative behavioural hypothesis, let us consider the case of any number of alternative outcomes. It is a reasonable behavioural hypothesis that truckies act to maximise utility (V), and that they constantly evaluate alternative ways of achieving outcomes (s) consistent with this behavioural postulate. An alternative outcome is chosen if and only if it provides the highest (indirect) utility, that is if:

(12) $V_s > \max V_j, j = 1, ..., M; j \neq s$

The probability that alternative s will be chosen is given by:

(13) $P_{s = \text{prob}} (V_s > \max V_j \; \forall j \in M; j \neq s)$

Let us define:

(14) $\eta_s = \max V_j - \mu_s , j = 1, ..., M; j \neq s$

The alternative s is chosen if and only if $\beta_s' X_s > \eta_s$. The unobserved effects are assumed to be independently and identically distributed extreme value type I. It can be shown that given a vector of exogenous variables, X, the distribution of $F(\eta_s)$ of η_s is:

(15) $$F(\eta_s) = \exp(\eta_s) / \left[\exp(\eta_s) + \sum_{\substack{j=1 \\ j \neq s}}^{M} \exp(\beta_j') X \right]$$

and the probability that the alternative s will be chosen is:

$$(16) \quad P_s = \frac{\exp(\beta_s' X)}{\sum_{j=1}^{M} \exp(\beta_j' X)}$$

This is the familiar multinomial logit model (McFadden 1981, Hensher and Johnson 1981, Greene 1990). To derive the selectivity regressor, let Φ denote the standard normal distribution function. The transformation $J = \Phi^{-1} F$ proposed by Lee (1983) is strictly increasing, and the transformed random variable η_s^* where $\eta_s^* = J(\eta_s)$ will be a standard normal variate. Since J is a strictly increasing transformation, the alternative s is chosen if, and only if $J(\beta_s' X) > \eta_s^*$. Since both the random variables ε_s and η_s^* are normally distributed, we assume that ε_s and η_s^* are jointly normally distributed. The specification implies that conditional on the alternative being chosen (Lee 1983):

$$(17) \quad y_s = \gamma_s' z - (\sigma_s \rho_s)\, \phi(J(\beta_s' x_s)) / F(\beta_s' x_s) + \xi_s$$

where $E(\xi_s | \text{ s is chosen}) = 0$, ϕ is the normal density function, σ_s is the standard deviation of the disturbance ε_s and ρ_s is the correlation coefficient of ε_s and η_s^*. The conditional variance of ξ is:

$$(18) \quad \text{var}(\xi_s \mid \text{s is chosen}) = \sigma_s^2 - (\sigma_s \rho_s)^2 \left[J(\beta_s' x) + \phi(J(\beta_s' x)) / F(\beta_s' x) \right]$$
$$* \phi(J(\beta_s' x)) / F(\beta_s' x).$$

Equation (17) can be estimated in two stages. First we estimate the logit choice model to obtain maximum likelihood parameter estimates for the choice between pill taking and non-pill taking (with the EMU from the self-imposed schedule choice included as a RHS variable). We then estimate equation (19) by OLS after substituting β_j', $j = 1, \ldots, M$ into equation (17):

$$(19) \quad y_s = \gamma_s' z - (\sigma_s \rho_s)\, \phi(J(\widehat{\beta_s'} x_s)) / F(\widehat{\beta_s'} x_s) + \bar{\xi}_s$$

where: $\bar{\xi}_s = \xi_s + \sigma_s \rho_s \left[\phi(J(\widehat{\beta_s'} x_s)) / F(\widehat{\beta_s'} x_s) - \phi(J(\beta_s' x_s)) / F(\beta_s' x_s) \right]$.

The unobserved effects $\bar{\xi}_s$ are heteroscedastic just as they are in the probit specification. A corrected asymptotic variance matrix is constructed to enable OLS estimation to accommodate this correction.

The final empirical results, after extensive testing of hypotheses representing each generic source of potential influence, are summarised in Tables 2 and 3 for the full sample (excluding owner driver fleet operators), and in Table 4 for the trip-specific models for the sub-sample of drivers reporting freight rates. Table 5, in the appendix, gives the mean and standard deviation of variables used in the models.

4. An Assessment of the Annual Economic Reward Model System

The total number of working hours per annum is the most important truck driver determined factor in establishing the opportunity for economic reward. Hours committed to the job have a significant influence on the amount of driving time obtained which in turn directly contributes to explaining variations in average weekly earnings net of truck expenses. Nine exogenous effects were identified as influences on the variations in total working hours across the sample of 791 truck drivers. All are statistically significant and with plausible signs. Hours of work are higher for independent owner drivers, sub-contractors and small company drivers compared to prime contractors and medium/large company drivers. We found a strong synergy between independent owner drivers and employee drivers in small companies (less than 6 employees).

Drivers who take pills either some of the time or on all trips tend to work longer hours, as do truckies who have higher annual truck repayments and those who have rejected loads in the past year for whatever reason. Compensating factors which act to reduce work hours are the aging of a truck driver and the inclusion of backload provisions where regular contracts are in place. Three additional variables condition the influence of background, lifestyle, sub-industry status and financial pressure on performance. These are the state in which a driver is based and the incidence of trips between Melbourne and Brisbane. West Australian based drivers tend to work longer hours, all other things being equal, for fairly obvious reasons: they usually have long hauls coast to coast. On the contrary, NSW based drivers tend, relative to drivers based in other states, to work shorter hours. The spatial variables provide an important contextual qualification, highlighting the comparative advantage of NSW based drivers in respect of work hours.

However when one considers the link between working hours and the proportion of such hours which are behind the wheel (directly productive hours if carrying a load) one finds that longer working hours do not lead to a higher percentage of driving time. It does however lead to a higher absolute amount of driving time. This is an important finding because it suggests that in order to improve one's chances of having more wheelhours one has to invest in a more than proportionally higher amount of non-driving time. This is the phenomenon of diseconomies of work time. This is what tends to produce the lifestyle characteristics associated with pills, lack of sleep, self-imposed schedules and bad diet. Three exogenous variables also contribute to the explanation of the variability in the incidence of wheelhours. Truck drivers with a higher complement of Sydney-Brisbane trips (SBTRIPS), and/or are employee drivers paid per trip (TRIPPY) and/or have regular contracts (RCALL) for all trips tend, other things being equal, to have a higher percentage of work time behind the wheel. This is an intuitively plausible finding. It particularly highlights the important role that regular contracts have in minimising the amount of unproductive or marginally productive non-driving time.

Through the influence of total work hours on the incidence of driving time, there is strong evidence to support the hypothesis that the greater the proportion of work time behind the wheel, the greater the economic rewards, after allowing for a number of contextual, background, lifestyle and other influences. The regular contract (RCALL) features in the direct sources of influence on weekly earnings. Truck drivers with no regular contracts tend to commit themselves to long periods of waiting to secure the next load. All other things being equal, there is a strong negative and increasingly negative impact on earnings from increasing amounts of waiting time (NXT..). The most noticeable reduction in earnings occurs when waiting exceeds 24 hours (NXTGT24).

Table 2 Determinants of the annual economic reward profile
Estimation method: Three Stage Least Squares (791 observations)

Explanatory Variables	Acronym	Parameter	t-value estimate
Equation 1: Log(Av. weekly earnings net of truck expenses) LINCPWKN			
Log(% time driving)	LDRVHRS	0.7860	2.60
Where no regular contract:			
Wait up to 12 hrs for next load (1,0)	NXTL12	-.2180	-2.80
Wait 12-24 hrs for next load (1,0)	NXT1224	-.2397	-2.71
Wait > 24 hrs for next load (1,0)	NXTGT24	-.4377	-4.20
OD years of outstanding loan repayments	OUTLOAN	-.1509	-7.55
Constant		*3.1814*	*2.54*
OLS r-squared		*0.16*	
Equation 2: Log(Incidence of driving time in total work hours) LDRVHRS			
Log(total work hours)	LWORKHRS	-.0878	-1.65
No. of Sydney-Brisbane trips	SBTRIPS	0.0067	3.14
Employee driver paid per trip (1,0)	TRIPPY	0.0748	3.98
All trips with a regular contract (1,0)	RCALL	0.0704	3.29
Constant		*4.4772*	*15.16*
OLS r-squared		*0.10*	
Equation 3: Log(Total work hours) LWORKHRS			
Age of driver	AGE	-0.0067	-5.98
Indep. OD & small co. driver (1,0)	ODINSC	0.0709	3.16
West Australia based (1,0)	WAB	0.1162	2.56
New South Wales based (1,0)	NSWB	-.1548	-7.07
No. of Melbourne-Brisbane trips	MBTRIPS	0.0096	2.56
Pill taking on some or every trip (1,0)	PILLS	0.0681	3.35
Log(annual truck repayments)	LREPAYC	0.0025	1.20
Backload provision for regular contracts (1,0)	BACKLOAD	-.0472	-2.30
Tendency to reject loads (1,0)	REJLOAD	0.0418	1.98
Constant		*4.815*	*98.8*
OLS r-squared		*0.23*	
Equation 4: Number of speeding fines in last 12 months FINES			
Log(total work hours)	LWORKHRS	3.9284	3.82
Pill taking on every trip (1,0)	AWAKE4	1.9051	3.43
Reject loads due to badpayers (1,0)	BADPAY	1.6403	1.70
No. of Sydney-Melbourne trips	SMTRIPS	0.0750	3.64
No. of annual sickdays	SICKDAYS	0.0174	2.10
Constant		*-16.88*	*-3.58*
OLS r-squared		*0.20*	
Equation 5: Number of log book fines in last 12 months FINEL			
Log(total work hours)	LWORKHRS	3.0841	3.74
Pill taking on every trip (1,0)	AWAKE4	1.3075	2.91
Reject loads due to badpayers (1,0)	BADPAY	3.1308	4.01
No. of annual sickdays	SICKDAYS	0.0232	3.45
Constant		*-13.274*	*-3.51*
OLS r-squared		*0.17*	

The financial burden of continuing loan commitments (OUTLOAN) has the expected negative impact on earnings. Owner drivers with a greater number of years of outstanding loan repayments tend to have lower earnings. This might be expected because of the correlation between the number of years of a loan (even allowing for the fact that loans were taken out at different periods prior to the survey period) and the actual repayments, which suggests that all other thing being equal that drivers with longer repayment periods increasingly are unable to keep net earnings up to a level equivalent to those with shorter or no repayment periods.

Two additional equations were linked into the earnings system to establish the existence of possible sources of influence on the number of speeding (FINES) and log book (FINEL) fines. As might be expected the incidence of fines is conditioned by the total amount of wheelhours which are in absolute terms positively correlated with working hours. The incidence of fines is statistically significant on the Sydney-Melbourne route (SMTRIPS) where both the quality of the Hume Highway and the apparently greater police surveillance contribute to explain this situation. Three other factors contribute to the higher amount of annual fines; the consumption of pills (PILLS), experience with bad payments (BADPAY) which has resulted in subsequent rejection of loads and the number of days off work due to sickness (SICKDAYS).

The full model system provides clear evidence to support arguments which suggest that an improvement in earnings may be achieved in an environment of regular contracts (or at least the amount of work time committed to achieving an acceptable earnings stream can be reduced by regular contracts), which flows through to a lesser dependence on pills and loss of business. It does not follow with certainty that a widespread introduction of regular contracts would result in an increase in earnings for all operators. Rather, this will depend on the extent of bidding for contracts which could result in a reduction in rates. The compensating benefit however is the significant reduction in unproductive working hours and the concomitant flow through to improved performance on the road.

5. An Assessment of the Trip Specific Activity Profile

The trip-specific model system results are summarised in Tables 3a and 3b. We begin with the bivariate probit model where we evaluate the extent to which the propensity to take pills and the self-imposition of a schedule jointly influence on-road speed (Table 3a).

Table 3a Determinants of the propensity to speed (total average speed) Estimation method I: FIML bivariate probit and selectivity regression (760 observations)

Explanatory Variables	Acronym	Parameter	t-value estimate
Equation 1: Joint determination of propensity to take pills on some or every trip and the propensity to self-impose schedules			
(i) Propensity to self-impose schedules (ARRB)			
Age of driver	AGE	-.091	-1.71
Co. or freight forwarder imposed schedules (1,0)	SCHARR	0.4204	4.26
Independent owner driver (1,0)	ODIOD	0.2365	1.89
No. of stops - sleep + rest activities	SLPREST	-.2031	-2.89
Average ratio drive/total time per trip leg	MEANPERC	0.0102	2.48
Constant		*-.1876*	*-.580*
(ii) Propensity to take pills on some or every trip (PILLS)			
Age of driver	AGE	-.0248	-4.18
Driver has always been a truckie (1,0)	NOPRVOCC	0.3851	3.30
Hours on road in prior 8 hours	ROAD8	0.0471	1.60
Hours sleeping in prior 8 hours	SLEEP8	-.0634	-3.75
Gross weight of truck	TRKWT	0.0402	3.16
Load is perishable cargo (1,0)	GDPER	0.3810	3.39
No. of speeding fines per annum	FINES	0.0850	3.98
Owner driver paid per load (1,0)	PAYTYPL	-.1902	-1.51
All trips with a regular contract (1,0)	RCALL	-.2564	-2.39
Constant		*0.0731*	*0.23*
Rho (ARRB,PILLS)		.0309	0.492
Log-likelihood		-956.25	
Equation 2: Log (Average speed per trip) LTOTASP			
Pill taking behaviour (1,0)	PILLS	0.0815	2.19
Sydney-Brisbane trip (1,0)	SYBR	-.0390	-2.11
Sydney-Melbourne trip (1,0)	SYML	0.0479	3.10
Age of driver	AGE	-.0022	-2.78
No. of no-sleep stops	NOSLEEP	0.0106	2.79
Co. or freight forwarder imposed schedules (1,0)	SCHARR	0.0188	1.50
Percent of trip time 6pm to 6am	EVEPERC	0.0004	1.60
Weekend trip (1,0)	DAYSTRT	0.0379	2.71
Rigid truck (1,0)	TRKRIG	-.1754	-4.58
Log(average ratio drive/total time per trip leg)	LMEANPRC	0.0971	3.33
Lambda (ARRB) - Selectivity		0.0024	0.31
Lambda (PILLS) - Selectivity		-.3180	-1.40
Constant		*3.9687*	*34.27*
Estimated correlation with selection equation ARRB		0.021	
Estimated correlation with selection equation PILLS		-.194	
Estimated disturbance standard deviation		0.164	
r-squared		0.20	
Equation 3: Log (Standard deviation of speed across legs) LSPEEDSD			
Pill taking behaviour (1,0)	PILLS	0.1170	0.80
Sydney-Brisbane trip (1,0)	SYBR	0.1300	1.49
No. of no-sleep stops	NOSLEEP	0.1732	10.03
Trip started before 8 am (1,0)	TSTL8	-.3291	-3.76
Standard deviation of each leg's drive/total time ratio	RATIOSD	2.1511	7.85
Lambda (ARRB) - Selectivity		0.0151	0.41
Lambda (PILLS) - Selectivity		0.0507	-.53
Constant		*1.4588*	*12.53*
Estimated correlation with selection equation ARRB	0.021		
Estimated correlation with selection equation PILLS	-.065		
Estimated disturbance standard deviation		0.7900	
r-squared		0.23	

The correlation between the unobserved influences on the probability of pill taking and the self-imposition of schedules is 0.0309. Using the Lagrange multiplier test (LM) under the null hypothesis that rho equals zero (the equivalence of two independent probit equations), the LM statistic value of 3.221 suggests that the hypothesis that rho equals zero cannot be rejected. Thus we would conclude that the bivariate probit specification behaves as if the two choices were independent.

The selectivity terms (Lambda's) in the average speed equation lead us to reject any statistical bias due to the inclusion/exclusion of drivers in each category of the self-imposed schedule treatments (ARRB); however this is not so with respect to pill taking although the confidence level is only 93%. Lambda contains information on the variances of the unobserved components of the probit equation and the selectivity regression equation as well as the correlation between them (Equations 10 and 11). The estimated correlation between the average speed equation and the pill taking equation is - 0.19 and its correlation with the self-imposed schedule equation is 0.021. This evidence suggests that if the self-imposed schedule is to influence average speed, it is unlikely to do so via its joint influence with the propensity to take pills. The possibility of other linkages is evaluated using a nested logit framework under the alternative hypothesis that on-road speed is influenced by pill taking which is itself influenced by self-imposed schedules (Table 3b).

Table 3b Determinants of the propensity to speed (total average speed) Estimation method II: sequential nested logit and selectivity regression (760 observations)

Explanatory Variables	Acronym	Parameter	t-value estimate
Equation 1: Propensity to self-impose schedules (ARRB)			
Age of driver	AGE	-.0149	-1.76
Co. or freight forwarder imposed schedules (1,0)	SCHARR	0.6871	4.28
Independent owner driver (1,0)	ODIOD	0.3954	1.91
No. of stops: sleep + rest activities	SLPREST	-.3366	-2.64
Average ratio drive/total time per trip leg	MEANPERC	0.0167	2.50
Constant		*-.3114*	*-.60*
Log-likelihood		-497.62	
Equation 2: Propensity to take pills on some or every trip (PILLS)			
Age of driver	AGE	-.0336	-3.40
Driver has always been a truckie (1,0)	NOPRVOCC	0.6302	3.32
Hours on road in prior 8 hours	ROAD8	0.0667	1.28
Hours sleeping in prior 8 hours	SLEEP8	-.1022	-3.67
Gross weight of truck	TRKWT	0.0699	2.66
Load is perishable cargo (1,0)	GDPER	0.5547	2.91
No. of speeding fines per annum	FINES	0.1355	3.45
Owner driver paid per load (1,0)	PAYTYPL	-.3815	-1.78
All trips with a regular contract (1,0)	RCALL	-.3798	-2.13
Expected maximum utility : ARRB	*EMU*	*0.4641*	*2.57*
Constant		*-.3239*	*-0.55*
Log-likelihood		-455.94	
Equation 3: Log (Average speed per trip) LTOTASP			
Pill taking behaviour (1,0)	PILLS	0.0714	1.95
Sydney-Brisbane trip (1,0)	SYBR	-.0304	-2.14
Sydney-Melbourne trip (1,0)	SYML	0.0472	3.06
Age of driver	AGE	-.0024	-3.10
No. of no-sleep stops	NOSLEEP	0.0106	2.78
Co. or freight forwarder imposed schedules (1,0)	SCHARR	0.0167	1.40
Percent of trip time 6pm-6am	EVEPERC	0.0004	1.75
Weekend trip (1,0)	DAYSTRT	0.0381	2.73
Rigid truck (1,0)	TRKRIG	-.1779	-4.68
Log(average ratio drive/total time per trip leg)	LMEANPRC	0.0951	3.23
Lambda (PILLS) - Selectivity		0-.0246	-1.0
Constant		*3.9863*	*35.09*
Correlation: rho and disturbance		-.151	
Standard error corrected for selection		0.163	
r-squared		0.20	
Equation 4: Log (Standard deviation of speed across legs) LSPEEDSD			
Pill taking behaviour	PILLS	0.0733	0.52
Sydney-Brisbane trip (1,0)	SYBR	0.1286	1.50
No. of no-sleep stops	NOSLEEP	0.1725	10.03
Trip started before 8 am (1,0)	TSTL8	-.3354	-3.82
Standard deviation of each leg's drive/total time ratio	RATIOSD	2.1492	7.86
Lambda (PILLS) - Selectivity		0.0180	0.19
Constant		*1.4826*	*13.02*
Correlation: rho and disturbance		-.0228	
Standard error corrected for selection		0.788	
r-squared		0.23	

The selectivity regression for the standard deviation of leg speeds (SPEEDSD) was not able to establish a statistically significant link between itself and the two selection equations with respective correlations of 0.021 (ARRB) and -0.065 (PILLS). Given the statistical non-significance of the pill taking endogenous dummy variable we are led to conclude that pill taking behaviour does not influence the variations in average speed between legs of a trip. However, the statistical significance of PILLS in the average speed equation (t-value = 2.19) provides statistically strong evidence to support the hypothesis that after accounting for possible selectivity, the propensity to take pills either on all trips or some trips does have a significant positive influence on trip speed. This important finding reinforces the evidence reported in Hensher and Battellino (1990). The self-imposed schedule dummy variable was statistically non-significant in both selectivity regression equations (with t-values less that 0.08).

The nested logit framework provides a statistically stronger relationship between pill taking, self-imposed schedules and speed. The expected maximum utility index linking the probability of self-imposed schedules and pill taking is statistically significant (t-value = 2.57) and of the correct sign for a nested structure consistent with the notion of random utility maximisation. A necessary and sufficient condition for consistency with utility maximisation is that the parameter of EMU is contained within the range 0.0 to 1.0. An estimated value of 0.46 indicates that there is a sequential recursive relationship between pill taking and self-imposed schedules. The probability of participating in pill taking is amongst other reasons influenced by the expected maximum utility emanating from the choice process associated with self-imposed schedule selection. After allowing for any possible selectivity in respect of pill taking in the population of long distance truck drivers, the evidence supports the hypothesis that there is a positive and statistically significant relationship between pill taking and trip speed. On average, drivers on pills tend, ceteris paribus, to drive at speeds 10 kph greater than drivers not on pills. This is typically a comparison of 90 vs 100 kph and 100 vs 110 kph.

Given the hierarchical linkages now established between speed, drugs and self-imposed schedules, we can interpret the findings on other factors influencing all three endogenous variables. Five exogenous variables had a statistically significant influence on the probability of a driver imposing a schedule. This self-imposition is more likely for younger (and because of its correlation) less experienced drivers. It is reinforced by (or may arise from) the imposition of a schedule from an employer or freight forwarder. Thirty-seven percent of the sample had such a constraint. Independent owner drivers representing 17.4% of the sample have a significantly higher propensity to self-impose schedules than do employee drivers, prime contractors and subcontractors. The analysis also suggests that drivers who tend to have a greater number of trip stops involving some component of sleep and rest (after allowing for the incidence of drive time in total trip time - MEANPERC, which is a highly correlated proxy for trip length) tend to have a lower probability of self-imposing schedules. This arises most plausibly because of the lesser amount of pressure on the driver's earning opportunity.

The factors influencing the probability that a driver will take pills are quite extensive. We consistently found that 9 exogenous variables explained the pill taking propensity within the sampled population. Forty-six per cent of the sample take pills either all the time or on some trips. Four variables have a negative relationship with the probability of taking pills: the age of the driver, the availability of regular contracts for this trip and all other trips, the opportunity for an owner driver to be paid on a per load basis (in comparison with payment per tonne or per kilometre for owner drivers and either by fixed salary, a percent of truck earnings or on a per trip basis for employee drivers), and the incidence of sleep in the 8 hours prior to trip commencement. The variables that have a positive influence on drug taking are drivers with no previous occupation (who have always been a truckie), hours on the road in the last 8 hours prior to commencing the current trip, the gross weight of the truck (proxying for the size and prestige of vehicles and in many cases debt on the truck), those drivers carrying perishables, and those drivers who tend to have the higher incidence of speeding fines.

These positive and negative influences when taken together are expressing a "lifestyle" phenomenon which in part is the historical product of pressures in the market to secure loads in order to earn an acceptable wage. Any assistance to this industry which can reduce the pressures in the market to a level which will reduce the reliance on pills must be desirable (even after allowing for the possibility of somewhat higher rates for moving goods). The important point is that the current rates have not internalised the negative externalities rampant in this industry, which have spawned a lifestyle encouraging pill taking in order to stay awake long enough to improve the financial situation. The use of stimulants is as widespread in the employee driver sector as it is in the owner driver sector, and is regarded by many drivers as an acceptable practice.

Two empirical measures of speed were used to capture the exposure to risk element of on-road performance. The first is the average speed across all legs (TOTASP), the second is the standard deviation of leg speeds (SPEEDSD). Extensive checking of the data was undertaken to ensure that the reported details on each leg's distance and time (including stop time) were reasonable. Comparisons between drivers on legs between the same locations provided an additional method of checking the reliability of implied speeds. This enabled us to ensure that the distances were accurate and highlighted any substantial discrepancy due to an unreliable reported travel time.

The set of trip-specific models yield intuitively plausible findings.

(i) Trip routes and speeding

Ceteris paribus, there is a tendency for drivers on the Sydney-Brisbane route (primarily the Pacific Highway) to have lower average speeds than drivers on other routes. Likewise trips between Sydney and Melbourne (primarily along the Hume Highway) tend to have average speeds higher than the sample average. The first evidence supports the concern to slow down due to the poor condition of the road whereas the higher speeds on the Hume are indicative of the better quality road. Therefore, there is evidence here of the general sensitivity of truck drivers to the quality of the roads. We should also remind ourselves of the evidence that trips along the Hume Highway tend to have a higher incidence of speeding fines.

(ii) Night time driving and speeding

A particularly important finding is that trips with a higher percentage of night-time driving (EVEPERC) are associated with higher average speeds. If this were the only factor influencing the temporal allocation of truck trips, then one may make a case for encouraging more daylight hours of travel. However this has a downside, in that there would be more trucks on the road during hours when more passenger vehicles are on the road. The larger non-rigid trucks tend to have higher speeds than rigid trucks. On average the rigid trucks travel 12 kph slower than the articulated vehicles. It is true however that the trip lengths are shorter for the rigid vehicles.

(iii) Trip length and speeding

Throughout the study we have noticed a consistent positive correlation between on-road performance and trip length. The strong positive relationship between MEANPERC and average speed (with an elasticity of 0.10) and between RATIOSD and the standard deviation of average leg speed reinforces this point. The option of mandated longer stops (say up to 12 hours) for trips over 500 kilometres is worthy of consideration from an immediate safety perspective. It may have undesirable financial implications because of the likely requirement for a second driver.

(iv) No sleep stops and speeding

Ceteris paribus, drivers with fewer no-sleep stops en route tend to have higher average speeds. This is also linked to the propensity to take pills and the imposition of schedules on 37% of trips by freight forwarders.

There is also a strong negative relationship between age of driver and average speed, as expected. All of these findings give confidence in the quality of the data - the evidence is intuitively plausible. Most of these influencing variables *individually* affect the average speed 5 kph above or below the average. Thus when combined, there are some substantial variations in average speeds attributable to sets of positive effects as well as sets of negative effects.

(v) Rates, payment method and speeding

The role of freight rates (or earnings for owner drivers) on trip speed has been incorporated in the trip-specific models for the sub-sample of 410 trips with complete information on rates. We report only the findings for the nested-logit model structure in Table 4. There is very strong evidence to support the primary hypothesis that the trip rate received by the owner driver (i.e. gross earnings) and the freight rate obtained by the company using an employee driver have a significant influence on the propensity to speed. The negative relationship is stronger for owner drivers as might be expected. The relationship with the standard deviation of leg speeds is not statistically significant.

The major impetus of this study has been confirmed: on-road performance is strongly linked to economic reward. An obvious proposition in many ways, but a proposition that has not been previously established in a scientific manner, nor a proposition which has previously been confirmed in the context of allowing for other direct and indirect influences on performance.

Table 4 Linking freight rates to on-road performance
Estimation method II: sequential nested logit and selectivity regression (410 observations)

Explanatory Variables	Acronym	Parameter	t-value estimate
Equation 1: Propensity to self-impose schedules (ARRB)			
Age of driver	AGE	-.0186	-1.64
Co. or freight forwarder imposed schedules (1,0)	SCHARR	0.3077	1.60
Independent owner driver (1,0)	ODIOD	0.2675	1.40
No. of stops: sleep + rest activities	SLPREST	-.5210	-3.12
Average ratio drive/total time per trip leg	MEANPERC	0.0060	0.64
Constant		*0.7696*	*1.03*
Log-likelihood		-265.22	
Equation 2: Propensity to take pills on some or every trip (PILLS)			
Age of driver	AGE	-.0332	-2.48
Driver has always been a truckie (1,0)	NOPRVOCC	0.5310	1.99
Hours on road in prior 8 hours	ROAD8	0.1481	1.85
Hours sleeping in prior 8 hours	SLEEP8	-.0796	-2.12
Gross weight of truck	TRKWT	0.0542	1.40
Load is perishable cargo (1,0)	GDPER	0.3972	1.53
No. of speeding fines per annum	FINES	0.1131	2.24
Owner driver paid per load (1,0)	PAYTYPL	-.5969	-2.52
All trips with a regular contract (1,0)	RCALL	-.4034	-1.55
Expected maximum utility : ARRB	*EMU*	*0.4556*	*2.00*
Constant		*0.0927*	*0.11*
Log-likelihood		-248.86	
Equation 3: Log (Average Speed per Trip) LTOTASP			
Pill taking behaviour (1,0)	PILLS	0.0743	-1.60
Sydney-Brisbane trip (1,0)	SYBR	-.0587	-2.75
Sydney-Melbourne trip (1,0)	SYML	0.0285	1.50
Age of driver	AGE	-.0029	-3.09
No. of no-sleep stops	NOSLEEP	0.0019	0.42
Co. or freight forwarder imposed schedules (1,0)	SCHARR	0.0395	2.50
Percent trip 6pm to 6am	EVEPERC	0.0068	2.00
Weekend trip (1,0)	DAYSTRT	0.0483	2.73
Rigid truck (1,0)	TRKRIG	-.1014	-1.94
Log(average ratio drive/total time per trip leg)	LMEANPRC	0.0778	1.94
Freight rate for owner drivers (c/km)	*DKMOD*	*-.00087*	*-6.13*
Freight rate for employer (c/km)	*DKMED*	*-.00051*	*-4.00*
Lambda (PILLS) - Selectivity		0.0554	1.72
Constant	*4.2430*	*27.20*	
Correlation: rho and disturbance		0.370	
Standard error corrected for selection		0.149	
r-squared		0.22	
Equation 4: Log (Standard deviation of speed across legs) LSPEEDSD			
Pill taking behaviour	PILLS	0.1987	1.04
Sydney-Brisbane trip (1,0)	SYBR	0.0566	0.58
No. of no-sleep stops	NOSLEEP	0.1148	5.68
Trip started before 8 am (1,0)	TSTL8	-.3046	-2.51
Standard deviation of each leg's drive/total time ratio	RATIOSD	1.3555	3.52
Freight rate for owner drivers (c/km)	*DKMOD*	*-.00071*	*-1.08*
Freight rate for employer (c/km)	*DKMED*	*-.00081*	*-1.37*
Lambda (PILLS) - Selectivity		0.06551	-.53
Constant		*1.9562*	*11.19*
Correlation: rho and disturbance		-.092	
Standard error corrected for selection		0.708	

r-squared	0.15

6. Conclusion

The influences on the performance of long distance truck drivers in Australia are related in a complex way. Although the centrepiece of a causal system is the linkage between potential earnings, lifestyle and pressures imposed on a driver by employers and the marketplace, there are some very explicit influences impinging on safe practices on the road where safety and exposure to risk are adequately represented by variations in average trip speed across the population of truck drivers.

The data obtained from 800 truck drivers are used herein to establish a first round understanding of some of the major endogenous linkages and exogenous determinants on safe practice in respect of a particular trip and its links with the macro environment for annual earnings. This has enabled us to scientifically investigate a large number of the anecdotes and qualitative “evidence” previously used to develop positions in respect of strategies to “rid the industry and the road environment of cowboys”.

Economic rewards to both owner drivers and employers of drivers have a major influence on the propensity to speed; but that in particular:

(i) it is the rate per se which acts to stimulate road practices in various forms in order to ensure that an acceptable level of total earnings (net of truck-related expenses) is obtained. Any deviation from a fixed salary tends to encourage practices designed to increase economic reward which are not synergetic with reducing exposure to risk.

(ii) the uncertainty of annual earnings encourages the practice of self-imposed schedules and the taking of stimulants to enable extension of the productive working week. While the extended working week does increase the earnings, the incidence of productive (i.e. driving) time decreases as total working hours increases. Any strategy which can reduce the uncertainty of earnings must reduce the hours of total work, increase the amount of sleep time and consequently reduce the incidence of self-imposed schedules and hence the use of stimulants.

Regular contracts may be a preferred form of load allocation, initially obtained by a process of competitive bidding, with possibly relatively short contracts in order to ensure that bid prices remain competitive. This may be the only way to minimise the amount of unproductive waiting time and to eventually prune the industry. Major implementation of competitive bidding in other transport industries is seen as a preferred alternative to complete economic deregulation primarily because of the inability of deregulation to manifest an acceptable program of internalising the negative externalities of unfettered competition.

Loan repayments on a truck are a major financial commitment of owner drivers. Thus strategies to ensure that the financing of trucks is achieved with least burden would improve the net earnings of the owner driver sector.

The anecdotal evidence which tends to lay the blame for bad on-road behaviour on owner drivers is fallacious. Small company employee drivers have some of the worst industry practices in respect of speeding, use of stimulants and incidence of fines. Indeed many of the influences on variations in on-road performance, pill taking and self-imposition of schedules which often lead to speeding are not correlated with whether a driver is an owner driver or an employee driver. The distinction between owner driver and employee driver is somewhat arbitrary and misleading in the current context. A much more useful classification is in terms of the nature of contracts.

Lifestyle factors appear to have evolved as a result of the ease of entry to the industry coupled with its highly competitive nature which demands non-routine and unpredictable work practices for a significant number of drivers in the industry. There appears to be a case for much more stringent safety regulations centred on the health of the driver as distinct from the "health of the rig". There is a great temptation for commentators to argue that if someone wants to enter this industry, get burdened with high debts and work excessive hours to "make a quid" then they should be allowed to. This may be acceptable wisdom if safety of human resources at large were not at risk. It is precisely because of the negative externalities aligned to safety that changes are required in the competitive practices in the industry. The transactions costs are sufficiently high to warrant some restrictions on competitive practices *in* the market. Competition *for* the market should be given serious consideration.

Appendix

Table 5 Mean and standard deviation of variables used in the models

DESCRIPTION		ACRONYM	MEAN	STD DEV
Age of driver		AGE	37.50	8.99
Self-imposed arrival time (1,0)	TS	ARRB	.58	
Pill taking every trip (1,0)		AWAKE4	.09	
Backload provision for regular contracts (1,0)		BACKLOAD	.39	
Reject loads due to bad payers (1,0)		BADPAY	.03	
Weekend start to trip (1,0)	TS	DAYSTRT	.24	
Percent of time spent driving		DRVHRS	64.75	15.97
Percent of trip time 6pm to 6am	TS	EVEPERC *	59.92	26.23
No. of log book fines per annum		FINEL	1.25	3.54
No. of speeding fines per annum		FINES	1.80	4.34
Load is perishable cargo (1,0)	TS	GDPER	.24	
No. of Melbourne - Brisbane trips		MBTRIPS	.65	1.45
Av. ratio drive/total time per trip leg	TS	MEANPERC *	57.71	11.64
Driver has always been a truckie (1,0)		NOPRVOCC	.25	
No. of no sleep stops	TS	NOSLEEP	2.30	1.73
Where no regular contract:				
Wait up to 12 hours for next load (1,0)		NXTL12 *	.09	
Wait 12-24 hours for next load (1,0)		NXT1224 *	.07	
Wait > 24 hours for next load (1,0)		NXTG24 *	.05	
New South Wales based (1,0)		NSWB	.34	
Independent owner driver (1,0)		ODIOD	.17	
Independent OD and small co. driver (1,0)		ODINSC	.42	
Owner driver paid by load (1,0)	TS	PAYTPL *	.51	
Pill taking on some or every trip (1,0)		PILLS	.46	
Std dev of each leg's drive/total time ratio	TS	RATIOSD *	.29	.09
All trips with a regular contract (1,0)		RCALL	.32	
Tendency to reject loads (1,0)		REJLOAD	.41	
Annual truck repayments ($'000s)		REPAYC *	26.35	17.29
Hours on road in 8 hours prior to trip	TS	ROAD8	.79	1.62
No. of Sydney - Brisbane trips		SBTRIPS	1.02	2.25
Co. or freight forwarder imposed schedule (1,0)	TS	SCHARR	.36	
No. of annual sick days		SICKDAYS	6.10	18.60
Hours sleeping in 8 hours prior to trip	TS	SLEEP8	2.55	3.06
No. of stops - sleep + rest activities	TS	SLPREST	.30	.63
No. of Sydney - Melbourne trips		SMTRIPS	2.04	3.06
Standard deviation of trip leg speed	TS	SPEEDSD *	16.7	9.87
Sydney to Brisbane trip (1,0)	TS	SYBR	.05	
Sydney to Melbourne trip (1,0)	TS	SYML	.03	
Total average speed on sampled trip		TOTASP *	81.06	12.60
Employee driver paid per trip (1,0)		TRIPPY *	.64	
Gross weight of truck		TRKWT	17.05	3.83
Rigid truck (1,0)		TRKRIG	.03	
Trip started before 8am (1,0)	TS	TSTL8	.13	
West Australia based (1,0)		WAB	.05	
Total weekly work hours		WORKHRS	105.11	29.85

Note: Standard deviation is missing for variables coded as (1,0).
* indicates not full sample of 820 trips.
TS = variable is specific to the sampled trip.

Descriptive Background of Survey Sample

Some of the main findings from the descriptive analysis are summarised below.

Driver characteristics
- the majority of truck drivers (70%) had over 10 years experience driving large trucks on a regular basis
- the average number of annual vehicle kilometres driven by drivers in the sample was around 200,000 kms
- the majority of drivers (75%) were in the age group 25 to 44 years
- 25% of drivers had no previous occupation other than truck driving. For the others a range of occupations was represented, primarily the trades, farmers and general labourers, but also a significant number of managerial and professional positions

Income / payment
- the survey highlighted the low level of income earned by drivers, particularly owner drivers (36% earned less than $15,000 in 1989-90)
- the majority of employee drivers (79%) were paid directly in relation to the earnings of the truck

Work environment
- drivers believed that they worked an average of 105 hours per week. This included all work activities both on and off the road. Of this, about 65% on average was estimated to be driving time
- a considerable amount of time is spent by drivers in off-road work activities before embarking on the trip. Approximately 3.5 hours were spent on work related activities, such as unloading from a previous trip, loading for the next trip and maintenance of the truck, before beginning to drive
- approximately 35% of all drivers were travelling to a set schedule for the sampled trip
- but 60% of drivers maintained that even if they were not set a schedule by the freight forwarder they were aiming for their own self-imposed time of arrival. This was dictated primarily by concerns to be first in the queue to be unloaded and then to obtain the next load

Behaviour / on-road performance
- drivers from small companies recorded the highest average trip speed for the sampled trip (82.01 kph compared with the average for the sample of 81.06 kph)
- a higher average trip speed for the sampled trip was found on the longer trips
- the younger, less experienced drivers recorded the highest average trip speed on the sampled trip (those driving for less than 5 years had an average speed of 82.14 kph and those aged 17-24 years of age had an average speed of 84.72 kph compared with a sample average of 81.06 kph)
- 46% of drivers admitted to taking stimulant drugs at least on some trips
- 17% of drivers had been involved in a crash in the 2 years preceding the survey. Owner drivers and small company drivers were more likely to have been involved in more crashes than the other types of driver

Truck
- 40% of trucks were less than 3 years old. Owner drivers were more likely to have older trucks than any of the other types of driver
- the high cost of the commitment of financing the truck was highlighted by the low level of deposit of most owner drivers and the short period of the loan. The average loan period was 4.25 years and average monthly repayments were around $2,500
- repayments on the truck were the second highest component (after fuel) of total expenses for owner drivers
- at the time of the survey (September - October 1990) 13% of drivers were driving trucks which were fitted with a speed limiter. This varied greatly by type of driver with 42% of large company trucks being speed limited
- 19% of drivers were driving trucks which had a tachograph fitted

Driver comments
- the main issues confronting the industry mentioned by drivers were the low level of freight rates relative to their operating costs and the high cost of fuel and taxes

- the most important factors which drivers considered contributed to crashes involving heavy vehicles were the condition of the roads, the behaviour of other vehicle drivers, fatigue on the part of the truck driver and lack of driving skills by the truck driver
- drivers were very supportive of the need for specialised driver training courses to upgrade the skills of truck drivers and to improve their image with the general public. 80% of drivers were in favour of introducing driver training courses

REFERENCES

AUSTROADS (1991): *Management of Heavy Vehicle Driver Safety Project -Discussion Paper for Stakeholder Comment on Problems, Potential Countermeasures, Stakeholder Responsibilities and Accountability Arrangement.*

Barnow, B., G. Cain and A. Goldberger (1981): "Issues in the Analysis of Selectivity Bias". In E. Stromsdorfer and G. Farkas (eds.) *Evaluation Studies Review Annual,* Vol. 5, Sage, Beverly Hills, California.

Greene, W.H. (1981): "Sample Selection Bias as a Specification Error: A Comment". *Econometrica*, 49, 795-798.

Greene, W.H. (1990): *Econometric Analysis*. Macmillan Publishing Company, New York.

Hensher, D.A. (1986): "Sequential and full information maximum likelihood estimation of a nested logit model". *Review of Economics and Statistics*, LXVIII (4), 657-667.

Hensher, D.A. and H.C. Battellino (1990): "Long Distance Trucking: Why Do Truckies Speed?". *Papers of the Australasian Transport Research Forum*, 15, Part 2, 537-554.

Hensher, D.A., H.C. Battellino, J. Gee and R.F. Daniels (1991): *Long Distance Truck Drivers: Economic Reward and On-road Performance,* CR 99. Federal Office of Road Safety, Canberra, December.

Hensher, D.A., R. Daniels, and H.C. Battellino (1992): "Safety and Productivity in the Long Distance Trucking Industry". *Proceedings 16th Australian Road Research Board Conference*, Part 4, 219-235.

Hensher, D.A. and L.W. Johnson (1981): *Applied Discrete-Choice Modelling,* Croom Helm, London and John Wiley, New York.

Lee, L.F. (1983): "Generalised Econometric Models with Selectivity". *Econometrica*, 51, 507-512.

McFadden, D. (1981): "Econometric Models of Probabilistic Choice". In Manski, C.F. and McFadden, D. (eds.) *Structural Analysis of Discrete Data with Econometric Applications,* MIT Press, Cambridge.

Savage, I. (1989): "The Economic Underpinning of Transportation Safety Control", Department of Economics, Northwestern, Evanston, Illinois, August (mimeo).

Staysafe 15 (1989): From the Joint Standing Committee Upon Road Safety, *Alert Drivers, and Safe Speeds for Heavy Vehicles*.

Sweatman, P.F., K.J. Ogden, N. Haworth, A.P. Vulcan and R.A. Pearson (1990): *NSW Heavy Vehicle Crash Study Final Technical Report* prepared for Federal Office of Road Safety, CR92, CR5/90, August 1990.