Working Paper #05-20

October 2005

Adverse Network Effects, Moral Hazard, and the Case of Sport-Utility Vehicles

Matthew G. Nagler
Lehman College, The City University of New York

Adverse Network Effects, Moral Hazard, and the Case of Sport-Utility Vehicles

Matthew G. Nagler
Lehman College
The City University of New York

October 2005

PRELIMINARY DRAFT – DO NOT CITE OR QUOTE WITHOUT PERMISSION

I would like to thank William T. Dickens and Bradley Wimmer for helpful conversations. Financial support from the NET Institute (www.NETinst.org) is also gratefully acknowledged. All errors are mine alone.

JEL Codes: D00, D12, K10
Keywords: Network Externalities, Moral Hazard, Highway Safety, Discrete Choice Models

Adverse Network Effects, Moral Hazard, and the Case of Sport-Utility Vehicles

Abstract

The paper examines a class of phenomena that combine adverse network effects with moral hazard, using the motor vehicle market as an example to develop and illustrate the key concepts. It is hypothesized that consumers behave as if there is a network externality with respect to vehicle size: the more large vehicles there are on the roads, the greater a consumer's propensity to seek protection from them by driving a large vehicle herself. One consequence of this is that motor vehicle manufacturers are discouraged from making large vehicles less hazardous to other motorists. The paper measures the network effect and consequent moral hazard using disaggregate data on choice of vehicle type and related household characteristics, combined with a state-level measure of the incidence of traffic fatalities. The results show that for each 1 million light trucks that replace cars, between 961 and 1,812 would-be car buyers decide to buy a light truck instead, in reaction to the increased risk of death posed by the incremental light trucks. This network effect, when run in reverse, creates egregious incentives for vehicle manufacturers: for every life saved due to safety innovations that make light trucks less deadly to other motorists, manufacturers can expect to sell about 31 fewer light trucks.

Matthew G. Nagler
Department of Economics, Accounting and Business Administration
Lehman College
The City University of New York
250 Bedford Park Boulevard West
Bronx, NY 10468
718-960-8461 (office)
718-960-1173 (fax)
matthew.nagler@lehman.cuny.edu

1. Introduction

When a good exhibits a network externality, the value of a unit of the good increases with the number of units consumed in aggregate (Economides, 1996). Generally, this only has to be true in a *relative* sense; that is, my consumption of the network good may make other consumers of the good better off, or *non*-consumers of the good worse off, or both. The overall welfare effect of more people joining a network, then, is ambiguous; it depends on the balance of positive membership externalities and negative non-membership externalities that, taken together, make up a network externality.

Given the possibility of network effects with adverse consequences for welfare, a particular concern arises when some agent has the incentive and ability to manipulate the size (or perceived size) of a network externality to increase her own gain at the expense of the public good. This paper characterizes and provides guidance for identifying and measuring a class of phenomena that combine adverse network effects with moral hazard. A theoretical model is used to illustrate the welfare implications that arise from the set of conditions that characterize these phenomena. Through empirical analysis of a case example, the market for motor vehicles, the paper demonstrates that the characterizing conditions give rise to a quantifiable network effect and moral hazard problem. The results have important public policy implications, both in the motor vehicle case and beyond it.

Previous work has shown that large vehicles, such as pickup trucks and sport-utility vehicles (SUVs), protect their occupants in collisions better than smaller vehicles. However, this protection comes at the cost of increased risk of injury and death to the passengers of other vehicles on the road (White, 2004). We hypothesize that, as a consequence of these conditions, consumers behave as if there is a network externality with respect to vehicle size. That is, the more SUVs or other light trucks there are on the roads, the greater a consumer's propensity to seek protection from them by driving an SUV or other light truck herself.[1] An important consequence of this response behavior is adverse incentives that discourage motor vehicle manufacturers from implementing changes to make large vehicles less hazardous to other motorists. If they do so, they reduce the perceived size of the network externality and so can expect to sell fewer large vehicles, which are more profitable than small vehicles.

The empirical results show that these effects are more than just an object of speculation. Combining disaggregate data on vehicle choice and related household characteristics with a state-level measure of the incidence of traffic fatalities, we estimate the effect of risk of death in an accident on the decision to purchase a light truck versus a car. The results are then combined with White's (2004) estimates of the effect of light truck ownership on the incidence of traffic fatalities, allowing measurement of the network effect. We find that for each 1 million light trucks that replace cars, between 961 and 1,812 would-be car buyers decide to buy a light truck instead, in reaction to the increased risk of death posed by the incremental light trucks on the road. This network effect, when run in reverse, creates egregious incentives for motor vehicle manufacturers: for every life saved due to safety innovations that make light trucks less deadly to other motorists, manufacturers can expect to sell about 31 fewer light trucks.

[1] Note that there need not be an actual network externality (i.e., value of a unit increases with quantity consumed in aggregate) for consumers to *behave as if* there is a network externality.

Other applications of the theory include so-called "white flight" and the role of real estate agents (Georgetown Law Journal, 1970; Harvard Law Review, 1980), community spending standards and the role of marketing (see, e.g., Frank, 2005), and labor market "rat race" outcomes (see, e.g., Landers et al., 1996). As a class, these situations represent complex social and economic problems. The presence of network externalities implies a role for collective action to improve welfare in each case. However, the fact that these situations are characterized by moral hazard suggests that these and similar policy problems must be viewed as involving the potential for adversarial confrontations between private and public interests. Such problems must be handled carefully and with recognition of the special costs and risks they may involve.

The rest of the paper is structured as follows. Section 2 outlines the conditions that characterize adverse network effects with moral hazard and presents a simple model of their effects on welfare. Section 3 looks at several examples and applications of the theory. Section 4 describes the empirical results from the motor vehicle case. Section 5 discusses policy implications. Section 6 concludes.

2. Theory

2.1 Characterization

Adverse network effects with moral hazard represent a special case of network externalities and so require a more elaborate characterization. Four conditions characterize the relevant phenomena. First, there exists an activity (e.g., consuming a good) that exhibits a *negative externality*: when one person engages in the activity, other people are made worse off. Second, by engaging in the activity herself, a person *partially* *shields herself* against the negative effects of others' engagement. Third, the marginal utility of the shielding increases with the aggregate amount of engagement in the activity; that is, the more others perform the action in question, the greater the marginal value the shielding provides relative to no shielding. Fourth, there exists a third-party – sometimes a firm that transacts with the "engagers" – that (1) benefits increasingly the more people engage in the activity, and (2) can manipulate the intensity of the negative externality and the shielding effect. One possible variation involves two or more third-parties, in which the capabilities of manipulating the negative externality and the shielding effect belong to separate parties.

The motor vehicle example from the introduction illustrates how the four conditions might manifest themselves. The first condition, the negative externality, arises to the extent that an incremental SUV or light truck imposes an increased risk of injury and death on other motorists. The second condition, or shielding effect, arises to the extent that larger vehicles are perceived to protect their occupants better against injury or death in an accident than smaller vehicles. The third condition arises if people believe that the protection large vehicles afford becomes more valuable or essential the more large vehicles there are on the road. With respect to the fourth condition, the third-party in question would be the motor vehicle manufacturer. The condition is satisfied to the extent that the manufacturer earns a greater profit from selling a large vehicle than a small vehicle, and the manufacturer has some degree of control over both the risk of injury its vehicles impose on other motorists and the degree of protection its vehicles' occupants themselves receive against injury in an accident.[2]

[2] We consider whether these conditions likely apply to the motor vehicle market in section 3.

It is instructive to view the third-party as a principal and the engagers as agents, and to think of the principal as playing a "good cop – bad cop" game with the agents. In this analogy, manipulating the shielding effect is playing "good cop," and manipulating the negative externality is playing "bad cop." The shielding effect and negative externality might be used, respectively, as a carrot and stick to obtain desired action by the agent, much as police might use "good cop" and "bad cop" personas to obtain a confession from a crime suspect. The analogy is limited: the interrogated suspect is deliberately led to believe that the good cop and bad cop are acting independently, whereas such deception is not a critical characteristic of the phenomena we are considering. But our analogy is still instructive to the extent that "good cop" and "bad cop" behaviors work mutualistically; as will be demonstrated, the negative externality is only valuable to the principal to the extent that there is a shielding effect, and vice versa.[3]

As mentioned above, the principal and agent might be seller-and-buyer of a good or service (or buyer-and-seller), though not necessarily. In the next section, we present a simple model to characterize the incentives and shed light on the welfare consequences associated with adverse network effects. In this model, the principal does not transact with agents, but benefits from their actions through a positive externality.[4]

2.2 A Model

Consider agents *i* distributed uniformly based on a parameter $v_i \in [v_0 - 1, v_0]$ where $1 \geq v_0 \geq 0$; the number of agents is normalized to 1. Agents must decide whether

[3] Situations with adverse network effects are not the same as prisonners' dilemma games. Prisonners' dilemma games have a dominant strategy, whereas adverse network effect situations do not. Put another way, the relative value of a strategy under adverse network effects depends on the strategies chosen by the other players, whereas in a classic prisonners' dilemma it would not.

[4] A future version of the model will examine the more general case of a transacting principal and agent.

or not to take a certain action. They are made worse off when other agents take the action, incurring a loss $L(Q) = \lambda Q$, where Q is the number of agents that take the action and $\lambda \geq 0$. The marginal utility to an agent of taking the action, however, is generally positively affected by other agents taking the action. If an agent i does not take the action, she receives $U_i = -L(Q)$. If the agent does take the action, she receives $U_i = \Psi_i - L(Q)$, where $\Psi_i = v_i + \theta L(Q)$ is the agent's reservation price for the action and $0 \leq \theta \leq 1$. An agent will take the action if $\Psi_i > 0$.

This formulation – specifically, if $\theta\lambda > 0$ – implies a network externality: increases in aggregate action-taking, Q, beget an increase in reservation prices. We will refer to $\theta\lambda$ as the size of the network externality.

The principal is able to manipulate the values of λ and θ up or down, at a cost. Assume that λ and θ take on baseline values of λ_0 and θ_0, respectively, when not being manipulated by the principal; and that $\theta_0\lambda_0 < 1$, so small exogenous changes in Q do not result in a corner solution in which all agents take the action or all agents do not take the action. The principal's profit function can be written:

$$\Pi = Q(\lambda,\theta) - C(\lambda,\theta) \tag{1}$$

where the cost function, $C(\lambda,\theta)$, is symmetric relative to $\lambda = \lambda_0$ and $\theta = \theta_0$. Specifically, $C_\lambda(\lambda) \geq 0$ and $C_{\lambda\lambda}(\lambda) > 0$ for $\lambda \geq \lambda_0$; $C_\theta(\theta) \geq 0$ and $C_{\theta\theta}(\theta) > 0$ for $\theta \geq \theta_0$; $C_\lambda(\lambda) = -C_\lambda(2\lambda_0 - \lambda)$, $C_\theta(\theta) = -C_\theta(2\theta_0 - \theta)$, $C_{\lambda\lambda}(\lambda) = C_{\lambda\lambda}(2\lambda_0 - \lambda)$, and

$C_{\theta\theta}(\theta) = C_{\theta\theta}(2\theta_0 - \theta)$; and $C_{\lambda\theta} = 0$ everywhere.[5] We assume further that $C(\lambda_0, \theta_0) = 0$. The cost function is continuous everywhere, and it is twice differentiable everywhere except at $\lambda = \lambda_0$ and $\theta = \theta_0$.

We define welfare in terms of agents' utilities to be:[6]

$$W \equiv \int_{v_0 - 1}^{v_0} U_i dv_i \tag{2}$$

In equilibrium, there will exist $v^* \in [v_0 - 1, v_0]$ such that, for all $v_i \in [v^*, v_0]$, agents take the action, while all other agents do not take the action. Thus, $Q = v_0 - v^*$. For interior solutions, $\Psi_{v^*} = 0$, so:

$$\begin{aligned}
& v^* + \theta L(Q) = 0 \\
& \Rightarrow v^* + \theta\lambda\left(v_0 - v^*\right) = 0 \\
& \Rightarrow v^* + \theta\lambda v_0 - \theta\lambda v^* = 0 \\
& \Rightarrow v^* - \theta\lambda v^* = -\theta\lambda v_0 \\
& \Rightarrow v^* = \frac{-\theta\lambda v_0}{1 - \theta\lambda}
\end{aligned} \tag{3}$$

It is evident from (3) that $v^* < 0$ when both λ and θ are greater than 0 (as long as $\theta\lambda < 1$).[7] This might not be interior to $[v_0 - 1, v_0]$ as, for example, when $v_0 = 1$. Imposing $v^* > v_0 - 1$ in (3):

---

[5] These expressions use the substitutions $\lambda = \lambda_0 + (\lambda - \lambda_0)$ and $2\lambda_0 - \lambda = \lambda_0 - (\lambda - \lambda_0)$ and analogous substitutions corresponding to θ.

[6] Because the principal in the model does not transact with the agents and returns to the principal from agent action are a positive externality, the relationship of the principal's utility to agents' utility is not defined – in fact, any such definition would be arbitrary. Accordingly, we give the principal's utility zero weight in the welfare function, effectively treating the principal in the way that a regulator is typically treated in industrial organization models.

[7] $\theta\lambda \geq 1$ would cause *Q* to blow up, precipitating the corner solution $v^* = v_0 - 1$.

$$
\begin{aligned}
&v^* = \frac{-\theta\lambda v_0}{1-\theta\lambda} > v_0 - 1 \\
&\Rightarrow -\theta\lambda v_0 > (v_0 - 1)(1-\theta\lambda) = v_0 - 1 - \theta\lambda v_0 + \theta\lambda \\
&\Rightarrow v_0 < 1-\theta\lambda
\end{aligned} \tag{4}
$$

We modify (3) accordingly:

$$
v^* = \begin{cases} \dfrac{-\theta\lambda v_0}{1-\theta\lambda} & \text{if } v_0 \le 1-\theta\lambda \\ v_0 - 1 & \text{if } v_0 > 1-\theta\lambda \end{cases} \tag{5}
$$

The following derivatives show how changes in parameter values affect v^*:

$$
\frac{dv^*}{d\lambda} = \begin{cases} \dfrac{-\theta v_0(1-\theta\lambda) - (-\theta\lambda v_0)(-\theta)}{(1-\theta\lambda)^2} = \dfrac{-\theta v_0 + \theta^2\lambda v_0 - \theta^2\lambda v_0}{(1-\theta\lambda)^2} = \dfrac{-\theta v_0}{(1-\theta\lambda)^2} \le 0 & \text{if } v_0 \le 1-\theta\lambda \\ 0 & \text{if } v_0 > 1-\theta\lambda \end{cases}
$$

$$
\frac{dv^*}{d\theta} = \begin{cases} \dfrac{-\lambda v_0(1-\theta\lambda) - (-\theta\lambda v_0)(-\lambda)}{(1-\theta\lambda)^2} = \dfrac{-\lambda v_0 + \lambda^2\theta v_0 - \lambda^2\theta v_0}{(1-\theta\lambda)^2} = \dfrac{-\lambda v_0}{(1-\theta\lambda)^2} \le 0 & \text{if } v_0 \le 1-\theta\lambda \\ 0 & \text{if } v_0 > 1-\theta\lambda \end{cases}
$$

(6)

$$
\frac{dv^*}{dv_0} = \begin{cases} \dfrac{-\theta\lambda}{1-\theta\lambda} \le 0 & \text{if } v_0 \le 1-\theta\lambda \\ 1 & \text{if } v_0 > 1-\theta\lambda \end{cases} \tag{7}
$$

Note that increasing *either* the size of the negative externality, λ, or the degree of shielding afforded to agents that take the desired action, θ, has a positive impact on the number of agents taking the action. Further, the two manipulations are symmetric in their effect: when $\lambda = \theta$, the impact of either manipulation is the same.

Now consider the principal's problem. The principal chooses λ and θ to maximize (1). We begin by ruling out the principal's reduction of λ or θ as an optimizing strategy. This is set forth in the following proposition and corollary.

PROPOSITION 1: *The principal will never choose to reduce either the negative externality,* λ*, or shielding effect,* θ*, relative to their baseline levels.*

Proof: Suppose, for λ_0 strictly greater than zero, the principal *does* choose to reduce λ to some level λ_1 such that $0 < \lambda_1 < \lambda_0$. Marginal profit is given by:

$$\frac{\partial \Pi}{\partial \lambda} = \frac{\partial Q}{\partial \lambda} - C_\lambda = -\frac{\partial v^*}{\partial \lambda} - C_\lambda = \frac{\theta v_0}{(1-\theta\lambda)^2} - C_\lambda \tag{8}$$

Since C_λ is strictly negative on $[\lambda_1, \lambda_0)$, marginal profit is strictly positive on this interval. Therefore, the principal is better off setting $\lambda = \lambda_0$, implying $\lambda = \lambda_1$ is not a maximizing choice. An analogous contradiction can be derived for θ. ■

COROLLARY 1: *The principal will never choose to reduce the size of the network externality,* $\theta\lambda$.

The first proposition and corollary have important implications. When a network externality involving adverse effects is in place, the principal will never seek to reduce its size. After all, network externalities result in more agents doing what the principal wants. In the motor vehicle case, an implication is that vehicle makers will not, where only their own profit is concerned, engage in R&D to make pickup trucks or SUVs safer to other vehicles.

Restricting attention now to $\lambda > \lambda_0$ and $\theta > \theta_0$, we consider the conditions for a maximum. The first-order conditions for the principal are:

$$\frac{\partial Q}{\partial \lambda} - C_\lambda = 0 \Rightarrow -\frac{dv^*}{d\lambda} - C_\lambda = \frac{\theta v_0}{(1-\theta\lambda)^2} - C_\lambda = 0$$
$$\frac{\partial Q}{\partial \theta} - C_\theta = 0 \Rightarrow -\frac{dv^*}{d\theta} - C_\theta = \frac{\lambda v_0}{(1-\theta\lambda)^2} - C_\theta = 0 \qquad (9)$$
$$\lambda \geq 0 \quad 0 \leq \theta \leq 1$$

Thus, an interior solution must observe $\lambda\theta < 1$: as λ and θ approach this boundary, the marginal product $\frac{\partial Q}{\partial \lambda}$ blows up, so a corner solution at $v^* = v_0 - 1$ would be reached before $\lambda\theta \geq 1$.

The second-order sufficient conditions for a maximum are that the first principal minor of the system's Hessian be negative and its determinant positive. The Hessian is

$$H \equiv \begin{bmatrix} \frac{\partial^2 \Pi}{\partial \lambda^2} & \frac{\partial^2 \Pi}{\partial \lambda \partial \theta} \\ \frac{\partial^2 \Pi}{\partial \lambda \partial \theta} & \frac{\partial^2 \Pi}{\partial \theta^2} \end{bmatrix} = \begin{bmatrix} \frac{2\theta^2 v_0}{(1-\theta\lambda)^3} - C_{\lambda\lambda} & \frac{v_0(1+\theta\lambda)}{(1-\theta\lambda)^3} \\ \frac{v_0(1+\theta\lambda)}{(1-\theta\lambda)^3} & \frac{2\lambda^2 v_0}{(1-\theta\lambda)^3} - C_{\theta\theta} \end{bmatrix} \qquad (10)$$

and its determinant is given by:

$$|H| = \left[\frac{2\theta^2 v_0}{(1-\theta\lambda)^3} - C_{\lambda\lambda}\right]\left[\frac{2\lambda^2 v_0}{(1-\theta\lambda)^3} - C_{\theta\theta}\right] - \left(\frac{v_0(1+\theta\lambda)}{(1-\theta\lambda)^3}\right)^2 \qquad (11)$$

For a maximum, then, the second derivatives of *Q* with respect to λ and θ, which are positive, must be small enough relative to the corresponding second derivatives of the cost function to guarantee that the diagonal elements of the Hessian are *both* negative. Otherwise, either the determinant will be negative or the first principal minor will be positive. Further, since the second term of (11) is positive, the requirements on the relative sizes of these second derivatives are made even more stringent. Intuitively, increases in λ and θ affect *Q* at an increasing rate because of the network effect; that is, larger values of λ and θ mean that further increases in these parameters are transmitted into increases in *Q* more rapidly. In order for there to be an interior maximum, the cost of further increases in λ and θ must rise faster than the returns to the increases. Otherwise, the principal will continue to raise one or both of these parameters until all agents take the desired action (i.e., implying a corner solution at $v^* = v_0 - 1$).

Another requirement for an interior maximum is based on the first-order conditions, given the second-order conditions just discussed. We require:

$$C_\theta\big|_{\theta=\theta_0} \le \frac{\lambda v_0}{\left(1-\theta_0\lambda\right)^2} \text{ and } C_\lambda\big|_{\lambda=\lambda_0} \le \frac{\theta v_0}{\left(1-\theta\lambda_0\right)^2} \tag{12}$$

If one of these conditions is not met – say, the condition on C_θ – the principal will choose a corner solution at $\theta = \theta_0$. An interior maximum may still be chosen with respect to λ; the conditions operate independently of each other.

A third requirement concerns the upper bound condition $\theta \le 1$. We require:

$$C_\theta\big|_{\theta=1} \ge \frac{\lambda v_0}{\left(1-\lambda\right)^2} \tag{13}$$

Otherwise the principal will choose a corner solution at $\theta = 1$.

We state the following lemma:

LEMMA 1: *There exists an interior maximum for the principal's optimization problem on* $\lambda \ge \lambda_0$ *and* $\theta_0 \le \theta \le 1$ *if (1) the second derivatives of cost with respect to* λ *and* θ *are large relative to the second derivatives of Q with respect to* λ *and* θ*, (2)* $C_\theta\big|_{\theta=\theta_0} \le \frac{\lambda v_0}{\left(1-\theta_0\lambda\right)^2}$ *and* $C_\lambda\big|_{\lambda=\lambda_0} \le \frac{\theta v_0}{\left(1-\theta\lambda_0\right)^2}$*, and (3)* $C_\theta\big|_{\theta=1} \ge \frac{\lambda v_0}{\left(1-\lambda\right)^2}$.

Our second main result follows from the second condition in the lemma, when strict inequality holds.

PROPOSITION 2: *The principal will increase the size of the network externality if* either *(i) the marginal cost of increasing the negative externality,* λ *, evaluated at* λ_0 *; or (ii) the marginal cost of increasing the shielding effect,* θ *, evaluated at* θ_0 *; is strictly less than the marginal effect of doing so on the number of agents, Q, who take the desired action.*

Thus, the principal's decision to increase the size of the network externality, by increasing the negative externality and/or the shielding effect, depends on a simple comparison of private cost to private benefit.

The following corollary establishes an important link between the negative externality and shielding effect, alluded to earlier in the "good cop – bad cop" discussion.

COROLLARY 2: *The profitability to the principal of increasing the negative externality,* λ *, depends upon there being a positive level of the shielding effect,* θ *. Conversely, the profitability to the principal of increasing the shielding effect,* θ *, depends upon there being a positive level of the negative externality,* λ *.*

Proof. $\frac{\partial v^*}{\partial \lambda} = 0$ when $\theta = 0$, and $\frac{\partial v^*}{\partial \theta} = 0$ when $\lambda = 0$. ■

That is, when agents are not given the opportunity to shield themselves partially against the negative externality by doing what the principal wants, exacerbating agent losses by enlarging the externality does not precipitate additional desired agent actions.

A welfare result for λ is needed to establish that manipulation of this variable indeed constitutes moral hazard. We state the following proposition:

PROPOSITION 3: *Increasing the negative externality, λ, unambiguously diminishes welfare.*

Proof: See Appendix.

In the motor vehicle context, Proposition 2 and Proposition 3 together imply that vehicle makers may have an incentive to make SUVs and other light trucks less safe for other motorists, even though doing so clearly decreases motorists' welfare. As we recall from Proposition 2, the incentive to make light trucks less safe depends only the private benefit of doing so exceeding the private cost of manipulation. Private and social benefits likely diverge because the risk of death caused by light trucks also drives sales for light trucks.

Next, we derive welfare results for θ:

PROPOSITION 4: *Increasing the shielding effect, θ, reduces welfare if $\theta < \frac{\lambda - v_0}{\lambda^2}$ and increases welfare if $\theta > \frac{\lambda - v_0}{\lambda^2}$.*

Proof. See Appendix.

Interestingly, increasing θ, the degree of shielding afforded to people that take the principal's desired action, does not unambiguously increase agents' welfare. When λ is relatively small (i.e., less than v_0), welfare always increases with θ. But when $\lambda > v_0$, welfare increases with θ only when θ is sufficiently large; otherwise, the social costs that θ imposes by encouraging more agents to take the action outweigh the benefits that it provides in reducing agent losses. This is because, when θ is relatively small, the number of inframarginal agents (i.e., already taking the action) is small relative to the number of marginal agents, all else being equal. Both sets of agents benefit from increases to θ, but marginal agents enlarge the negative externality while inframarginal agents do not. So, the benefits from increases to θ are gained at lower social cost when θ is larger than when it is smaller, given $\lambda > v_0$.

The implications in the motor vehicle case may seem counterintuitive. Better safety protections for the occupants of SUVs and other light trucks are *not* socially beneficial when light trucks impose large risks on other motorists, *unless* those safety protections are already quite substantial. Thus the socially optimal strategy with respect to interior safety in light trucks is ambiguous when the externally posed risk is large: it might involve maximal protection (i.e., $\theta = \frac{1-v_0}{\lambda}$) or minimal protection (i.e., $\theta = 0$, no different than for cars).

2.3 Summary and Application to Empirics

The model demonstrates several theoretical outcomes of the four conditions described at the beginning of this section, and it provides a basis for empirically estimating these outcomes in applicable situations. First, the characterizing conditions imply an actual or perceived network externality with respect to the action in question. Second, these conditions imply that the third-party/principal will wish to increase the negative externality and/or shielding effect when the private benefit to doing so exceeds the private cost. Third, increasing the negative externality (and sometimes the shielding effect) is detrimental to welfare, thus the third-party exhibits moral hazard.

The model shows that the network externality is a function of a negative externality combined with a shielding effect. Thus, the network effect may be measured by estimating two things: the negative externality involved in taking the action in question, and the agent's shielding response function to that negative externality (that is, the effect of an increase in the negative outcome that results from the negative externality on the agent's propensity to choose the action in question).

Since increasing the negative externality is typically in the third-party's interests, according to the model, moral hazard may be measured in terms of the tradeoff between benefit to the third-party from incremental agent actions and the benefit to agents (and, hence, society) of mitigating the negative outcome that results from the negative externality. This may be accomplished by examining the change in the agent's shielding response function due to different values of the negative externality. Since the negative externality and the agent's shielding response are both estimated when measuring the network effect, no further estimation is needed to generate a measure of the moral hazard;

one only needs to fit the existing model of agent response with different hypothetical values of the negative externality.

In the motor vehicle case, one of the two critical components of the network externality – the negative externality of vehicle size – has already been measured empirically by White (2004). In section 4 of this paper, we estimate the agent's shielding response function.

3. Examples and Applications

The incentive and welfare problems illustrated in the model may accrue to a variety of market situations, as adverse network effects combined with moral hazard may characterize a range of economic phenomena. In this section, we consider three applications of the adverse network effects model.

3.1 Motor Vehicles

Americans have been increasingly replacing cars with SUVs and pickup trucks and then replacing these vehicles with even larger SUVs and pickups. From 1980 to 2000, the share of motor vehicles that are light trucks increased from 22% to 39% (White, 2004). Concurrently, there has been an alarming increase in the number of deaths and serious injuries in crashes on the nation's roads, a trend that some analysts have attributed to the increasing prevalence of SUVs (Bradsher, 2002; Varian, 2003). Highway fatalities in the United States, which fell steadily from 54,600 in 1972 to 34,900 in 1992, rose during the decade that followed to hit 38,300 in 2002 (Varian, 2003). Meanwhile, vehicle makers have employed advertising strategies that create the perception that SUVs are safer than cars (Bradsher, 2002, pp. 127-8); and the notion that SUVs confer protection on their owners while menacing others has led some to characterize the SUV fad as an "arms race" (Bradsher, 2002, p. xix). In view of this, it makes sense – or at least it is not entirely preposterous – to ask: do motor vehicle manufacturers have a vested interest in making light trucks *less* safe to other motorists?

The answer depends on whether the four conditions outlined in the previous section are satisfied for this market. We consider each condition in turn. White's (2004) demonstration that an incremental light truck imposes an increased risk of death on other motorists provides evidence that the first condition is satisfied. In an extensive empirical study of the determinants of serious injury and death in accidents, based on data from the U. S. National Highway Traffic Safety Administration, White shows that for each 1 million light trucks that replace cars, between 46 and 67 additional people external to those light trucks (i.e., car occupants, pedestrians, bicyclists, or motorcyclists) are killed per year.[8]

Satisfaction of the second and third conditions is supported by anecdotal evidence. White (2004) asserts that the promise of superior protection in crashes is an important reason for the popularity of larger vehicles. However, hard empirical evidence from actual consumer decisions would bolster the argument that consumers increasingly choose light trucks as the risk of injury and/or death on the road grows. We will examine such evidence in Section 4 of the paper.

The fourth condition, which must be examined with respect to motor vehicle manufacturers, consists of two parts. First, motor vehicle makers do appear to earn

[8] These figures are calculated by taking the incremental number of crashes with light trucks involving fatalities outside the light truck (i.e., total external effects from White's Table 5), which range from 40 to 58, and multiplying by 1.15, the average number of deaths per fatal crash (White 2004, p. 349).

substantially greater profit from selling larger vehicles, particularly SUVs. Bradsher (2002, pp. 84-7) explains that the combination of low production costs associated with pickup trucks with luxury car pricing has enabled SUVs to achieve unprecedented profit margins, as high as $15,000 per vehicle. Second, manufacturers do have control over both the degree of protection afforded to the occupants of its vehicles and the risk of injury and death its vehicles impose on other motorists. Few would argue with the ability of manufacturers to manipulate the degree of interior protection: a number of features such as crumple zones, lateral metal bars, and airbags may be included or not included by manufacturers in the design of a particular vehicle model, affecting the safety of the model's occupants in a crash. Similarly, discretionary design features influence the effect of vehicles on the safety of other motorists in crash situations. Light trucks are characterized by several features, including the height of the vehicle front-end, frontal stiffness, and grille guards, that increase their deadliness to car occupants that collide with them (Bradsher, 2002, pp. 166-206). The risk of death imposed on other motorists could be reduced by modifying some or all of these features.

3.2 "White Flight"

The adverse network effects model also sheds light on the mechanisms that led whites to depart cities for the suburbs, and inner suburbs for outer suburbs, in the U.S. during the second half of the 20th century. White flight may be thought of as having involved two sets of negative externalities. First, families fleeing the cities imposed losses generally on society, in that benefits accruing to having integrated communities were lost, segregation was itself undesirable, and open space was turned into new suburbs at an unnecessary rate. Second, they imposed perceived negative impacts specifically on those remaining behind in the cities, such as undesired change in the character of communities and fear of decline in property values. By fleeing to the suburbs, a white family could protect itself against this latter set of effects of others' flight. Analyses of white flight (see, e.g., Harvard Law Review, 1980) suggest that whites do appear to have resorted to flight partially out of a desire for such shielding. The dynamics of flight further suggest that it tends to accelerate as the total share of whites fleeing a community grows; this is reflected in the notion of the "tipping point," a point at which a partially integrated community begins to move inexorably toward becoming an all-black segregated community (Harvard Law Review, 1980, p. 942). Thus, white flight seems to have exhibited a network externality: the more white families departed, the greater the perceived value of departing (or cost of not departing) for remaining white families.

In this context, real estate brokers and suburban developers appear to have accelerated the process of white flight by consciously manipulating the network externality. Real estate brokers engaged in a notorious practice called "blockbusting," whereby a realtor would generate business by "warning" white families in a neighborhood about the imminent entry of blacks (Harvard Law Review, 1980, p. 943). This practice was intended to stoke racial fears and precipitate panic sales of property, generating additional real estate commissions.

The Fair Housing Act of 1968 declared blockbusting illegal, but this prohibition is unlikely to have eliminated the moral hazard problem inherent in white flight, as our model suggests. Though a realtor or developer might have been prohibited from actively stoking racial animus, various marketing and selling strategies were still available to profit off the extant level of animus. For example, real estate developers could build increasingly insular subdivisions with gates and other security features to provide effective shielding against the losses feared as a consequence of racial migration trends. Realtors could then market such communities to whites as “enclaves,” or as “safe” and “exclusive,” conveying legally and without overt racial meaning that these communities offered the protection whites were looking for. Such practices might reduce welfare, our model suggests, if racial animus is great enough and the ability of suburban communities to truly insulate whites is not sufficiently great.

3.3 Community Consumption Standards

A growing literature in economics recognizes the role of social considerations in consumption decisions and associated market outcomes (Scitovsky, 1976; Frank, 1999; Becker and Murphy, 2000; Luttmer, 2005). Chao and Schor (1998), for example, show that for “socially visible” products, such as designer jeans and sports cars, price and quality are less highly correlated than for non-visible products. Frank (2005) describes the role of social influences in the decision of whether to purchase a house in a top-ranked school district or an average school district: the prospects of one’s child are affected by this decision because they depend on the child’s position *relative* to other children, whose positions in turn depend upon the decisions their parents make. Analyses such as these are pointing out what sociologists have long noted but economists have, until recently, failed to account for: that there is a non-“utilitarian” component to individuals’ utility, perhaps more for certain types of goods than others, that is a function of other people’s demonstrated or stated preferences for those goods. In other words, the decisions of people as a group establish standards for consumption, and individual utility from consumption is often based on positioning relative to the standard.

Socially driven consumption may be motivated more by a stick than a carrot if one fears significant losses from failing to buy a given good. Otnes and Pleck (2003), for example, describe how affluent couples may face social sanctions if they opt for a simple rather than a lavish wedding (p. 21). Such pressures do not only guide decisions of the bride and groom; it is generally considered *de rigueur* for guests to spend as much on a wedding gift as they believe is being spent on them at the reception (Otnes and Pleck, 2003, p. 19). In such cases, the individual decision to adopt the higher-priced product (e.g., wedding, gift, school district) involves a negative externality in that it reinforces pressures on others to conform. However, the decision also shields the individual partially from the losses incurred by non-conformists, and such shielding becomes more valuable in relative terms the more people adopt the higher-priced product and the greater the associated pressure to conform. All of this is consistent with the adverse network effects model and, therefore, the view of community-influenced consumption decisions as involving a network externality.

Our model sheds new light on community consumption standards, particularly the implications for third-party manipulation of these standards. Marketers, the model suggests, have an incentive to increase the extent to which people are driven to purchase their products by social pressures. Such influence might be brought to bear through advertising that suggests that the consumer will be more fully accepted by others if she consumes the product or rejected by others if she fails to consume the product.[9] It may

[9] See, for example, Otnes and Pleck (2003, p. 64) for a description of “guilt appeals” used by DeBeers to market its diamonds.

be brought more subtly through the fostering of organizations and social events intended to create the sense of a community of people involved in consumption of a given brand or product (Algesheimer et al., 2005; Kozinets, 2001). Similarly, sales persons may be in a position to influence norms for spending amounts and expected quality levels on unfamiliar items (Kalra et al., 2003).

There is increasing recognition that community consumption standards have troublesome consequences for welfare. These include household debt and bankruptcy, savings shortfalls, long work hours, failure to fund essential public services, and resource waste (Frank, 1999, 2005). Tied to these concerns is the notion that some forms of consumption, even when chosen willfully by an individual, do not provide satisfaction, and are thus, by implication, allocatively inefficient. As Amitai Etzioni (1998, p. 630) remarks: "There is … good reason to suggest that the combination of artificial fanning of needs and cultural pressures maintain people in consumeristic roles when these are not truly or deeply satisfying." As with other phenomena characterized by adverse network effects, then, the profit motive with respect to community consumption standards is placed in conflict with the public interest.

4. Empirical Evidence

4.1 Specification and Regression Results

In this section, we use microlevel data on motor vehicle choice and its determinants to estimate the network effect with respect to vehicle size and the associated moral hazard problem. The basic specification is a binomial logit regression that explains the individual household's decision to purchase a light truck (i.e., SUV, van, minivan, or pickup truck) versus a car.[10] The dependent variable is a dummy variable equaling one if a light truck was purchased. To construct this variable, household-level data on vehicles owned was drawn from the Consumer Expenditure Survey ("CEX") of the Bureau of Labor Statistics.[11] The sample for the estimation was composed of the subset consisting of cars or light trucks purchased new in 2003 or 2004 for those households for which it was possible to determine the state of residence, resulting in approximately 1,000 purchase decision observations.[12] These observations were matched to explanatory variable data for 2003 corresponding to the household and its members.

The key explanatory variable is the probability that a car or light truck in the household's state of residence will be involved in a crash during the period of a year in which at least one occupant is killed. This "risk of death" is calculated for each state by dividing the number of vehicles experiencing a crash fatality by the number of registered vehicles.[13] Data on vehicle fatalities are from the National Highway Traffic Safety Administration ("NHTSA") [14]; data on vehicle registrations are from the Federal

---

[10] SUVs, vans, and pickup trucks are classified as light trucks, consistent with White (2004) and the U.S. Government, which was the source of all the data in the study.

[11] Public Use Microdata from the Consumer Expenditure Survey are available at http://www.bls.gov/cex/home.htm. They may also be downloaded through the Inter-University Consortium for Political and Social Research (http://www.icpsr.umich.edu/). The CEX is based on national probability sample of the U. S. civilian population.

[12] The household's state of residence was suppressed by the CEX for about 15% of observations to meet the Census Disclosure Review Board's criterion that the smallest geographically identifiable area have a population of at least 100,000. This could represent a limitation of our results.

[13] The number of vehicles (i.e., cars and light trucks) by state experiencing a crash fatality is estimated by taking the number of vehicle occupants killed in crashes by state and multiplying by the nationwide ratio of vehicles with deaths to occupants killed. The result is divided by the total number of car and light truck registrations by state to obtain a probability estimate.

[14] Source for passenger vehicle occupants killed by state: NHTSA Traffic Safety Facts 2003, p. 7 (available at http://www-nrd.nhtsa.dot.gov/pdf/nrd-30/NCSA/TSF2003/809773.pdf). Vehicles with deaths nationwide estimated from the NHTSA General Estimates System (available at http://www-nrd.nhtsa.dot.gov/departments/nrd-30/ncsa/GES.html) as weighted total of vehicles with at least one death, cars and light trucks only.

Highway Administration.[15] The variable is constructed for 2003. The hypothesis is that a higher risk of death leads to a greater propensity to buy light trucks as a way of shielding oneself and one's family members; thus the variable is predicted to have a positive sign.

Control variables are also included that capture characteristics of the household that were considered possible determinants of the decision to purchase a light truck. These include dummy variables for whether the household resides in a metropolitan area with a population less than 330,000, earns more than US$75,000 per year, and reports some portion of use of the vehicle in question as a business expense. Additional dummy variables track whether the person completing the survey is black, is male, is not single (i.e., either married, widowed, divorced or separated), and works in a blue collar profession.[16] Separate variables are included for the number of cars and light trucks owned by the household, the number of people under the age of 18 living in the household, the amount of money spent on tobacco products by the household in the current quarter, and the age of the person completing the survey.[17] Household-level weights are used to make the sample representative of all households.

In addition, a number of explanatory variables are included that consider interactions between household characteristics and the risk of death. The hypothesis behind these variables is that, when the risk of death increases, households with certain

[15] Federal Highway Administration, Highway Statistics 2003, section II (motor vehicles), tables MV-1 and MV-9 (available at http://www.fhwa.dot.gov/policy/ohim/hs03/index.htm). Light truck registrations include pickups, vans, sport utilities, and "other light" only.

[16] Blue collar professions include machine operators, assemblers, laborers, precision production professionals, craftspersons, repairpersons, farmers, foresters, and fisherpersons.

[17] Tobacco use is included as an indicator of a sort of high-risk, high-discount-rate lifestyle that might, we hypothesize, correlate positively with light truck ownership. Because tobacco is addictive and its demand highly inelastic, tobacco expenditures are considered predetermined (i.e., not endogenous) relative to the vehicle choice decision.

characteristics might increase their tendency to buy a light truck more than other households. For example, families with children might be more concerned about increased risks of death on the highway than families without children, so they might react more to such risks. The interaction variables include education level of the household member completing the survey, presence of children in the household, household pretax income, and household income interacted together with the presence of children. The data for these variables and the control variables above were taken from the 2003 CEX.

The results of two logit regressions are shown in Table 1: one incorporating the explanatory variables listed above, and one in which the male dummy and age variables are replaced by a dummy variable that tracks whether the person completing the survey is male and under 35 years of age. The risk of death variable has the predicted positive sign and is statistically significant in both models. Perhaps surprisingly, more educated people respond less to the increased risk of death than other people. Regarding the other variables, the regression estimates suggest that light trucks are more likely to be purchased by young males, people who are not black, and people who are not single. The incidence of light truck purchase increases with the number of people under 18 in the household, and when a household's income exceeds $75,000 per year. Taken together, the results reinforce the notion that the light truck today is more an accoutrement of affluent families than it is a professional tool of the working-class person: the high-income dummy variable is highly significant, while tobacco expenditure and the business expense and blue collar dummy variables are not significant.[18]

[18] These results point to the absurdity of the light-truck loophole, which exempts light trucks from the gas-guzzler tax applied to cars with poor gas mileage. The economic rationale for the exemption had been to

In what follows, we focus our attention on the risk of death variable and its implications.

4.2 Estimates of Network Effect

Consider what would happen if 1 million light trucks replaced cars on the road for an exogenous reason, such as a policy change or change in tastes. White's (2004) results show that between 24 and 44 additional crashes will occur per year involving deaths of car occupants, depending upon whether people change their driving behavior to reflect the lower safety record of light-truck drivers when they switch from a car to a truck (the latter figure) or not.[19] The present results tell us that these deaths would increase the propensity of households to buy light trucks, implying a network effect to light-truck purchases. We estimate the network effect by distributing the additional fatal crashes predicted by White (2004) proportionally across states based on the distribution of light truck registrations in 2003. We then re-fit the logit-based probabilities of light-truck purchase by applying the regression coefficient estimates in Table 1 to the revised risk of death. The baseline probabilities and re-fit probabilities are each averaged across the sample observations, applying the sampling weights. The two average probabilities are then multiplied by the total new unit sales of cars and light trucks for 2003, and the difference is taken as an estimate of incremental light-truck sales due to the increased risk of death.[20]

---

avoid raising the costs of vehicles primarily used for industrial purposes, which might, in turn, reduce industrial output. See Gayer (2004), p. 131.

[19] See White (2004), p. 345 for a full discussion.

[20] Source for new unit sales: U. S. Department of Transportation, Bureau of Transportation Statistics (available at http://www.bts.gov/publications/national_transportation_statistics/2005/html/table_01_17.html).

The results are shown in Table 2. The calculation is performed using results from each of the two specifications presented in Table 1, and using alternately White's (2004) "no behavior change" and "behavior change" assumptions, giving a total of four estimates. At minimum, incremental death risks cause 961 would-be car buyers to switch to light trucks when 1 million light trucks replace cars for exogenous reasons. Not surprisingly, the network effect is greater when driving behavior changes to reflect the vehicle driven: then, an incremental light truck causes a greater number of deaths, hence a greater incidence of defensive light-truck purchasing.

4.3 Estimates of Moral Hazard

Now consider a safety innovation involving a modification to an SUV or pickup truck that would reduce the risk of death it poses to other motorists to the risk level posed by cars. Suppose that the light trucks thus modified are otherwise identical in every detail to other light trucks – for example, a safety-enhanced Hummer H2 looks and drives just like an unenhanced Hummer H2. Suppose further that the safety innovation is developed at NHTSA using taxpayer money and is provided to vehicle makers for their implementation at no cost to them. Would the manufacturers implement it?

What complicates the answer to this question is that making light trucks less deadly decreases their salability – a consequence of the network effect. Consider an implementation of the hypothetical innovation on 1 million light trucks. Since the modified trucks are assumed otherwise to be no different than unmodified light trucks, driver behavior is assumed unchanged. According to White (2004), such a change would reduce the number of crashes fatal to car occupants by 24. Analogous to our method for estimating the network effect, we distribute the reduction in fatal crashes across states based on the distribution of light truck registrations in 2003. We then re-fit the probabilities of light-truck purchase by applying the regression coefficient estimates in Table 1 to the revised risk of death. The baseline probabilities and re-fit probabilities are each averaged across the sample observations, applying the sampling weights. The two average probabilities are then multiplied by the total new unit sales of cars and light trucks for 2003, and the difference is taken as an estimate of lost light-truck unit sales due to the decreased risk of death. We estimate that approximately 855 or 862 would-be light truck buyers choose to buy a car instead, using coefficient estimates from the first and second regressions, respectively.

The lost sales are then divided by the number of lives saved to obtain the manufacturer's tradeoff in vehicles per life; the results of this calculation are displayed in Table 2. Assuming 1.15 deaths per fatal crash, the number of lives saved is estimated to be $24 \times 1.15 = 27.6$.[21] The resulting tradeoff is $855.09/27.6 = 30.98$ vehicles per life for the first specification, and $861.89/27.6 = 31.23$ vehicles per life for the second specification. The lost sales do not represent a complete loss of earnings, as they are presumably offset by profits from the sale of substituted cars. Nevertheless, motor vehicle manufacturers are placed in the position of weighing their non-pecuniary concern for human life against the desire for higher profits from the sale of more profitable vehicles.

5. Policy Implications

[21] See White (2004), p. 349.

It is well-recognized that private incentives often fail to align with the public good. But when adverse network effects lead to moral hazard, policy problems associated with the divergence of public and private incentives are exacerbated. In these situations, the typical public policy solution aimed at reducing or eliminating an outcome damaging to the public good will be less effective or encounter greater resistance from private interests. Consequently, effective solutions entail a greater public cost.

Consider the effect of a policy that taxes motor vehicle makers a certain amount for every life lost by other motorists in crashes that involve their vehicles. Using the model set forth in section 2, this would be represented by imposing a per-unit tax, *t'*, on λ, where the level of *t'* is set by the policy maker to induce the socially optimal level of λ. Figure 1 illustrates the effect of the tax. Here $\lambda_P \equiv \lambda - \lambda_0$ represents the third-party's manipulation of λ relative to λ_0. The traditional textbook analysis of such a policy suggests that the firm will choose an abatement level that sets the marginal (private) cost of abatement equal to the per-unit tax.[22] Applying this in the model implies $\lambda_P^{'} < 0$ determined by $-C_\lambda\left(\lambda_P^{'}\right) = t'$, where $C_\lambda\left(\lambda_P^{'}\right) < 0$ for $\lambda_P^{'} < 0$ because abatement of λ is costly.

But this analysis ignores the value of λ to the firm in increasing output. The actual level of λ_P chosen by the firm given the tax – say, λ_P'' – arises from maximization of a modified version of equation (1):

$$\Pi = Q\left(\lambda,\theta\right) - C\left(\lambda,\theta\right) - t\lambda \tag{14}$$

The first-order conditions with respect to λ_P are

[22] See, e.g., Browning and Browning (1986), pp. 247-248.

$$\left(\frac{\partial Q}{\partial \lambda}-C_{\lambda}\right)\frac{d\lambda}{d\lambda_P}-t'=\frac{\theta v_0}{\left[1-\theta\left(\lambda_0+\lambda_P''\right)\right]^2}-C_{\lambda}\left(\lambda_P''\right)-t'=0$$
$$\Rightarrow \frac{\theta v_0}{\left[1-\theta\left(\lambda_0+\lambda_P''\right)\right]^2}-C_{\lambda}\left(\lambda_P''\right)=t' \tag{15}$$

Since the first term is generally greater than zero, $-C_{\lambda}\left(\lambda_P''\right)<t'$ implying $\lambda_P''>\lambda_P'$, thus the amount of abatement chosen by the firm is too low. Figure 1 is drawn showing $\lambda_P''<0$, but λ_P'' will be greater than zero if the firm's marginal product due to λ_P is large enough. In order to induce the optimal abatement level λ_P' given firm moral hazard, the policy maker must set $t''=t'+\frac{\theta v_0}{\left[1-\theta\left(\lambda_0+\lambda_P''\right)\right]^2}$.

However, an increase in the tax rate is tantamount to an increase in cost to a policy maker who is seeking to maximize political support (Peltzman, 1976; Hettich and Winer, 1988). The taxed parties – in this case, motor vehicle makers – will step up resistance when the tax on them is larger. So, optimal public policy comes at a greater political cost when adverse network effect-induced moral hazard is present.

In addition to informing generally on the cost-benefit calculation involved the mitigating the results of adverse network effects, the model can provide new insights on current policy debates. One example concerns the recent debate in the United States over new corporate average fuel economy regulations, often referred to as the CAFE standards. In proposing a new structure for the CAFE standards, the Bush Administration argued recently that when fuel economy standards are phased in too quickly, they lead to unnecessary highway deaths because small vehicles are too light and unsafe relative to larger vehicles. The new structure reflects this logic by allowing larger light trucks to meet lower fuel economy standards than smaller light trucks, whereas the previous structure had applied a single standard to all light trucks. The new standards are intended not to encourage manufacturers reduce the weight of their light trucks to improve mileage, but rather to accomplish mileage improvements though other innovations such as hybrid electric systems.[23]

While White's (2004) analysis raises concerns with respect to this policy, the analysis in the present paper identifies additional problematic issues. According to White (2004), increasing the average size of vehicles on the road will increase the number of highway deaths, not decrease it as the Bush Administration has suggested. This is because the negative external effects of vehicle size on other motorists outweigh the benefits of size to the vehicle's own occupants. Thus the proposed new CAFE standards may imperil more people than they protect. The present paper's analysis adds to these concerns problems stemming from consumer perceptions fostered by the Bush Administration's rhetoric. By stressing the importance of the size of one's own vehicle in ensuring the safety of one's occupants, the Administration increases the perception that the greater the risks on the road, the better off a consumer is driving a light truck. In the model's terminology, consumers are encouraged to perceive θ to be larger than they had thought previously, though θ itself is not changed by the policy.

There are three main effects, to the extent that the Administration's messages are treated as credible, new information. First, the Administration's rhetoric will act as a marketing message supporting light truck sales. That is, it will directly increase the demand for light trucks relative to cars, as people adjust their perceptions regarding the value of driving a light truck as protection against the existing risk of death. This, in turn,

[23] See, e.g., Danny Hakim, "Does Lighter Equal Deadlier?" *The New York Times*, August 28, 2005, section 4, p. 4.

will result in more highway fatalities.[24] Second, the network effect will be increased, causing future increases in the perceived risk of death to translate into a greater rate of switching from cars to light trucks. Third, as (9) shows, the increase in θ will increase manufacturers' moral hazard; that is, it will encourage manufacturers to increase λ, making light trucks even more unsafe to remaining car drivers, and further increasing the incidence of highway fatalities.

6. Conclusion

SUV-posed safety risks, white flight, and community consumption standards are recognized problems that raise important welfare concerns. This paper has shown that these problems are made more worrisome because they are set in motion by manipulatable network externalities. Each such problem has associated with it some private party with the power to exacerbate the problem and incentives contrary to the public good. This means that public policy solutions will generally involve greater implementation costs, in that they will entail conflict with or buyout of the private entity's adversarial interests. It is conceivable that, in some situations, the moral hazard issue will simply render policy solutions to such problems politically infeasible.

The role of this paper has been primarily to identify and describe the problem of adverse network effects with moral hazard and provide some empirical evidence of its existence in a particular case. Future research could make additional contributions in several ways. First, it would be illuminating to identify other examples of adverse

[24] Note the result here differs from the welfare effect of an actual increase in θ, as described in (A3). There is no real increase in the shielding provided to light truck passengers in the scenario we are considering, just an increase in the perceptions with respect to existing shielding.

network effects with moral hazard among current policy issues. Second, given that private-public sector conflict is a key feature of the adverse network effects problem, it would be helpful to develop specific conflict resolution approaches that can address associated policy issues at minimum cost and with the greatest chance of actual resolution. Third, in view of the role of moral hazard in the problem, a different approach to developing policy solutions could involve investigating incentive compatible mechanisms that the policymaker might use to obtain desired action from the adversarial private party.

Appendix

A.1 Proof of Proposition 3

Welfare at (λ, θ) is, for $v_0 \leq 1-\theta\lambda$,[25]

[25] We do not need to evaluate at $v_0 > 1-\theta\lambda$, because then $\frac{\partial v^*}{\partial \lambda} = 0$ and the principal will not increase λ.

$$
\begin{aligned}
W(\lambda,\theta) &= -L\left(v_0 - v^*\right) + \int_{v^*}^{v_0} \Psi_i \, dv_i \\
&= -L\left(v_0 + \frac{\theta\lambda v_0}{1-\theta\lambda}\right) + \left[v_0 - \frac{-\theta\lambda v_0}{1-\theta\lambda}\right]\theta L\left(v_0 + \frac{\theta\lambda v_0}{1-\theta\lambda}\right) + \int_{-\frac{\theta\lambda v_0}{1-\theta\lambda}}^{v_0} v_i \, dv_i \\
&= \left[\theta\left(v_0 + \frac{\theta\lambda v_0}{1-\theta\lambda}\right) - 1\right] L\left(v_0 + \frac{\theta\lambda v_0}{1-\theta\lambda}\right) + \left.\frac{v_i^{\,2}}{2}\right|_{-\frac{\theta\lambda v_0}{1-\theta\lambda}}^{v_0} \\
&= \left[\theta\left(\frac{v_0 - \theta\lambda v_0}{1-\theta\lambda} + \frac{\theta\lambda v_0}{1-\theta\lambda}\right) - 1\right]\left[\lambda\left(\frac{v_0 - \theta\lambda v_0}{1-\theta\lambda} + \frac{\theta\lambda v_0}{1-\theta\lambda}\right)\right] \\
&\quad + \frac{v_0^{\,2}}{2} - \frac{1}{2}\left(\frac{\theta\lambda v_0}{1-\theta\lambda}\right)^2 \\
&= \left[\theta\left(\frac{v_0}{1-\theta\lambda}\right) - 1\right]\left[\lambda\left(\frac{v_0}{1-\theta\lambda}\right)\right] + \frac{v_0^{\,2}}{2} - \frac{1}{2}\left(\frac{\theta\lambda v_0}{1-\theta\lambda}\right)^2 \\
&= \frac{\theta\lambda v_0^{\,2}}{\left(1-\theta\lambda\right)^2} - \frac{\lambda v_0}{1-\theta\lambda} + \frac{v_0^{\,2}}{2} - \frac{1}{2}\left(\frac{\theta\lambda v_0}{1-\theta\lambda}\right)^2 \\
&= \frac{\theta\lambda v_0^{\,2}}{\left(1-\theta\lambda\right)^2} - \frac{\lambda v_0 - \theta\lambda^2 v_0}{\left(1-\theta\lambda\right)^2} + \frac{1}{2}\frac{v_0^{\,2}\left(1-\theta\lambda\right)^2}{\left(1-\theta\lambda\right)^2} - \frac{1}{2}\left(\frac{\theta\lambda v_0}{1-\theta\lambda}\right)^2 \\
&= \frac{\theta\lambda v_0^{\,2}}{\left(1-\theta\lambda\right)^2} - \frac{\lambda v_0 - \theta\lambda^2 v_0}{\left(1-\theta\lambda\right)^2} + \frac{1}{2}\frac{v_0^{\,2} + \theta^2\lambda^2 v_0^{\,2} - 2\theta\lambda v_0^{\,2} - \left(\theta\lambda v_0\right)^2}{\left(1-\theta\lambda\right)^2} \\
&= \frac{\theta\lambda v_0^{\,2}}{\left(1-\theta\lambda\right)^2} - \frac{\lambda v_0 - \theta\lambda^2 v_0}{\left(1-\theta\lambda\right)^2} + \frac{1}{2}\frac{v_0^{\,2}}{\left(1-\theta\lambda\right)^2} - \frac{1}{2}\frac{2\theta\lambda v_0^{\,2}}{\left(1-\theta\lambda\right)^2} \\
&= -\frac{\lambda v_0 - \theta\lambda^2 v_0}{\left(1-\theta\lambda\right)^2} + \frac{1}{2}\frac{v_0^{\,2}}{\left(1-\theta\lambda\right)^2} = \frac{-\lambda v_0}{1-\theta\lambda} + \frac{1}{2}\frac{v_0^{\,2}}{\left(1-\theta\lambda\right)^2} \\
&= \frac{-v_0}{1-\theta\lambda}\left[\lambda - \frac{v_0/2}{1-\theta\lambda}\right]
\end{aligned}
\tag{A1}
$$

The derivative of W with respect to λ is, for $v_0 \le 1-\theta\lambda$,

$$\frac{\partial W}{\partial \lambda}=\frac{-v_0\theta}{(1-\theta\lambda)^2}\left[\lambda-\frac{v_0/2}{1-\theta\lambda}\right]+\frac{-v_0}{1-\theta\lambda}\left[1-\frac{v_0\theta/2}{(1-\theta\lambda)^2}\right]$$
$$=\frac{-v_0\theta\lambda}{(1-\theta\lambda)^2}+\frac{{v_0}^2\theta/2}{(1-\theta\lambda)^3}+\frac{-v_0}{1-\theta\lambda}+\frac{{v_0}^2\theta/2}{(1-\theta\lambda)^3}$$
$$=\frac{-v_0\theta\lambda}{(1-\theta\lambda)^2}+\frac{{v_0}^2\theta}{(1-\theta\lambda)^3}+\frac{-v_0(1-\theta\lambda)}{(1-\theta\lambda)^2}=\frac{-v_0\theta\lambda-v_0+v_0\theta\lambda}{(1-\theta\lambda)^2}+\frac{{v_0}^2\theta}{(1-\theta\lambda)^3} \quad \text{(A2)}$$
$$=\frac{-v_0(1-\theta\lambda)}{(1-\theta\lambda)^3}+\frac{{v_0}^2\theta}{(1-\theta\lambda)^3}=\frac{{v_0}^2\theta-v_0+\theta\lambda v_0}{(1-\theta\lambda)^3}=\frac{{v_0}^2\theta-v_0(1-\theta\lambda)}{(1-\theta\lambda)^3}$$
$$\le\frac{{v_0}^2\theta-{v_0}^2}{(1-\theta\lambda)^3}=\frac{{v_0}^2(\theta-1)}{(1-\theta\lambda)^3}\le 0$$

■

A.2 Proof of Proposition 4

Welfare at (λ,θ) is, for $v_0 \le 1-\theta\lambda$, as shown in (A1). The derivative of W with respect to θ is:

$$\frac{\partial W}{\partial \theta}=\frac{-\lambda v_0}{(1-\theta\lambda)^2}\left[\lambda-\frac{v_0/2}{1-\theta\lambda}\right]+\frac{-v_0}{1-\theta\lambda}\left[-\frac{\lambda v_0/2}{(1-\theta\lambda)^2}\right]$$
$$=\frac{-\lambda^2 v_0}{(1-\theta\lambda)^2}+\frac{\lambda {v_0}^2/2}{(1-\theta\lambda)^3}+\frac{\lambda {v_0}^2/2}{(1-\theta\lambda)^3}$$
$$=\frac{-\lambda^2 v_0}{(1-\theta\lambda)^2}+\frac{\lambda {v_0}^2}{(1-\theta\lambda)^3}$$
$$=\frac{-\lambda v_0}{(1-\theta\lambda)^2}\left(\lambda-\frac{v_0}{1-\theta\lambda}\right)$$
$$=\frac{-\lambda v_0}{(1-\theta\lambda)^3}\left(\lambda(1-\theta\lambda)-v_0\right)$$
$$=\frac{-\lambda v_0}{(1-\theta\lambda)^3}\left(\lambda-v_0-\theta\lambda^2\right)$$
$$=\frac{\lambda^3 v_0}{(1-\theta\lambda)^3}\left(\theta-\frac{\lambda-v_0}{\lambda^2}\right) \quad \text{(A3)}$$

Thus, $\frac{\partial W}{\partial \theta} > 0$ when $\theta > \frac{\lambda - v_0}{\lambda^2}$, and $\frac{\partial W}{\partial \theta} < 0$ when $\theta < \frac{\lambda - v_0}{\lambda^2}$. ■

References

Algesheimer, R., Dholakia, U. M., and Herrmann, A. (2005). "The Social Influence of Brand Community: Evidence from European Car Clubs." *Journal of Marketing, 69* (July), 19-34.

Becker, G. S., and Murphy, K. M. (2000). *Social Economics: Market Behavior in a Social Environment.* Cambridge, MA: Belknap Press / Harvard University Press.

Bradsher, K. (2002). *High and Mighty: SUVs – The World's Most Dangerous Vehicles and How They Got That Way.* New York: Public Affairs.

Browning, E. K., and Browning, J. M. (1986). *Microeconomic Theory and Applications,* 2nd edition. Boston: Little, Brown and Company.

Chao, A., and Schor, J. B. (1998). "Empirical Tests of Status Consumption: Evidence from Women's Cosmetics." *Journal of Economic Psychology, 19*, 107-131.

Economides, N. (1996). "The Economics of Networks." *International Journal of Industrial Organization, 14*, 673-699.

Etzioni, A. (1998). "Voluntary Simplicity: Characterization, Select Psychological Implications, and Societal Consequences." *Journal of Economic Psychology, 19,* 619-643.

Frank, R. H. (1999). *Luxury Fever: Why Money Fails to Satisfy in an Era of Excess.* New York: The Free Press.

Frank, R. H. (2005). "Progressive Consumption Taxation as a Remedy for the U. S. Savings Shortfall." *The Economists' Voice, 2:*3, Article 2. Available at http://www.bepress.com/ev.

Gayer, T. (2004). "The Fatality Risks of Sport-Utility Vehicles, Vans, and Pickups Relative to Cars." *The Journal of Risk and Uncertainty, 28*, 103-133.

Georgetown Law Journal. (1970). "Blockbusting." *59*, 170-189.

Harvard Law Review. (1980). "Benign Steering and Benign Quotas: The Validity of Race-Conscious Government Policies to Promote Residential Integration." *93*, 938-965.

Hettich, W., and Winer, S. L. (1988). “Economic and Political Foundations of Tax Structure.” *American Economic Review, 78* (September), 701-712.

Kalra, A., Shi, M., and Srinivasan, K. (2003). “Salesforce Compensation Scheme and Consumer Inferences.” *Management Science, 49* (May), 655-672.

Kozinets, R. V. (2001). “Utopian Enterprise: Articulating the Meanings of *Star Trek’s* Culture of Consumption.” *Journal of Consumer Research, 28* (June), 67-88.

Landers, R. M., Rebitzer, J. B., and Taylor, L. J. (1996). “Rat Race Redux: Adverse Selection in the Determination of Work Hours in Law Firms.” *American Economic Review, 86*, 329-348.

Luttmer, E. F. P. (2005). “Neighbors as Negatives: Relative Earnings and Well-Being.” *Quarterly Journal of Economics, 120* (August), 963-1002.

Otnes, C. C., and Pleck, E. H. (2003). *Cinderella Dreams: The Allure of the Lavish Wedding.* Berkeley: University of California Press.

Peltzman, S. (1976). “Toward a More General Theory of Regulation.” *Journal of Law and Economics, 19* (August), 219-240.

Scitovsky, T. (1976). *The Joyless Economy*. London: Oxford University Press.

Varian, H. R. (2003). “The True Costs of S.U.V.’s.” *The New York Times*, December 12.

White, M. J. (2004). “The ‘Arms Race’ on American Roads: The Effect of Sport Utility Vehicles and Pickup Trucks on Traffic Safety.” *Journal of Law and Economics, XLVII*, 333-355.

Table 1 **Results of Logit Regressions Explaining the Decision to Purchase a Light Truck Rather Than a Car**

Standard errors are in parentheses
N = 998

	Specification #1		Specification #2	
Risk of death	17042.4	(6669.0)[a]	16370.7	(6606.7)[b]
Small metro	0.0302	(.209)	-0.0123	(.210)
Income > $75K	0.577	(.163)[a]	0.623	(.164)[a]
Business expense	0.523	(.360)	0.517	(.350)
Black	-0.595	(.300)[b]	-0.637	(.296)[b]
Male	0.278	(.148)[c]		
Age	-0.0103	(.0057)[c]		
Young male			0.686	(.244)[a]
Not single	0.475	(.264)[c]	0.478	(.250)[c]
Blue collar	0.267	(.227)	0.336	(.222)
No. of vehicles	0.0358	(.0692)	0.0462	(.0689)
No. in HH < 18 yrs. old	0.214	(.090)[b]	0.249	(.0870)[a]
Tobacco exp.	-0.0008	(.0012)	-0.0006	(.0011)
Risk of death · Education	-965.4	(458.0)[b]	-893.4	(452.6)[b]
Risk of death · Kids	-1378.7	(2543.0)	-1225.2	(2498.5)
Risk of death · Income	-0.00785	(.0155)	-0.00870	(.0150)
Risk of death · Kids · Income	-0.00142	(.0207)	-0.000019	(.0202)
Constant	-0.997	(.379)[a]	-1.474	(.330)[a]

[a]Significant at $p < 0.01$ level. [c]Significant at $p < 0.10$ level.
[b]Significant at $p < 0.05$ level.

Table 2 **Estimates of Network Effect and Moral Hazard**

NETWORK EFFECT from replacing 1 million cars with light trucks: Increase in number of light trucks sold rather than cars

	Specification #1	Specification #2
No behavior change	+961	+967
Behavior change	+1800	+1812

MORAL HAZARD: Lost light truck unit sales per life saved through external safety innovations.

	Specification #1	Specification #2
No behavior change	-30.98	-31.23

Figure 1: A Tax on Lives Lost by Other Motorists