Provider insurance

Michael Manove*

Provider insurance is insurance offered by the provider of a product or service against losses or damages incurred in connection with the use of that product or service. It is demonstrated that a rate-setting agency, with no information about consumers, can design a provider-insurance mechanism that induces both the provider and the consumer to reduce losses efficiently, and, at the same time, transfers risk from the (risk-averse) consumer to the (risk-neutral) provider without moral hazard. The structure of the optimal provider-insurance mechanism is derived. The optimal mechanism must be imposed on a noncompetitive industry by regulators, but it can arise spontaneously in competitive industries and can be sustained.

1. Background

■ Whenever a consumer purchases a product or service from a provider, the consumer is in danger of incurring a loss should the product or service prove to be defective. The following economic problem presents itself: Can a mechanism be designed that gives the provider and the consumer the necessary information and incentives to reduce such losses efficiently? In this article we shall show that "provider insurance" with an appropriate premium structure can serve as such a mechanism. We define provider insurance to be any insurance offered by the provider of a product or service against losses or damages incurred in connection with the use of that product or service. Unlike warranties, provider insurance would often specify indemnities larger than the value of the service itself.

Because of the incentives it creates, a provider insurance policy is more than pure market insurance.[1] Rather, it is a tied sale of insurance and increased reliability. This is so because provider insurance will motivate the provider to take more care to reduce the probability of having to pay an indemnity. This kind of "moral hazard in reverse" will often increase economic efficiency.

As an illustration, consider the example of postal insurance. There is a common perception that the post office is more careful with insured parcels than with parcels that are not insured. Such behavior is appropriate from a social point of view. The reasons for a consumer to buy postal insurance for a package—its contents are valuable and fragile—are also good reasons for the mailman to be especially careful with that package. The purchase of postal insurance provides the post office with useful information about the value of a parcel to the consumer. At the same time, the fact that the post office is acting as the insurer provides it with an incentive to be careful.

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* Boston University.

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[1] For a review of related market-insurance concepts, see Erlich and Becker (1971).

For the purposes of our analysis, we shall postulate that the market in question has the following characteristics: An expected-profits-maximizing provider is producing a product or service that is subject to accidents. The provider can lower the probability of accidents by investing in accident prevention. Consumers of the product will suffer losses if an accident occurs, but they can decrease the extent of such losses by investing in loss-mitigation measures.[2] There is a rate-setting agency with the ability of structuring a provider-insurance program. This agency may be either an independent regulator or the provider itself. The agency knows the accident-prevention technology of the provider, but knows nothing of the loss-mitigation technologies of consumers. Accident prevention is a private good, i.e., the level of reliability provided for one consumer does not affect the cost of reliability to the others.[3]

Given a market of the type described, a provider-insurance mechanism can be designed that induces both provider and consumers to take socially optimal levels of care and that shifts all risk to the risk-neutral provider. The informational requirements of provider insurance are low. The provider must know how much insurance each consumer has purchased. The consumer must know the probability of an accident associated with each level of provider insurance. But the consumer does not have to monitor the performance of the provider; the incentives created by the insurance remove the provider's motivation to cheat. Neither the provider nor the agency needs to know anything about consumers' potential losses. Unlike preference revelation mechanisms in the tradition of Vickrey (1961), Groves (1973), and Clarke (1971), provider insurance works without any "leakage" of funds to or from third parties: i.e., all transactions involve only the provider and the consumers, and budgets are balanced. Although provider insurance can arise spontaneously in unregulated markets,[4] we believe that these characteristics make it an especially attractive mechanism for use in regulated markets.

In Section 2 we construct an abstract behavioral model of accident-cost and accident-frequency determination with risk-neutral consumers. We analyze the model to find conditions for socially optimal behavior and discuss various methods of inducing that behavior. In Section 3 we analyze behavior under a regulatory framework that sets the stage for the analysis of provider insurance. Section 4 introduces the risk-averse consumer, defines the provider-insurance mechanism, and describes its optimal structure. In Section 5 we show that the optimal provider-insurance mechanism can arise and be sustained in a competitive market. Section 6 contains concluding remarks.

2. Accident cost and frequency with risk-neutral consumers[5]

■ Let $x(p)$ be the cost to the provider of limiting the probability of an accident (in a given time period) to p. We assume that the probability of an accident will be p_0 if no accident-prevention measures are taken, so that $0 < p \leq p_0$ and $x(p_0) = 0$. Marginal accident-prevention cost is zero at p_0, increases as p decreases, and becomes arbitrarily large as p goes to zero. Therefore, $x'(p_0) = 0$, $x' < 0$ for $p < p_0$, and $x'(p) \rightarrow -\infty$ as

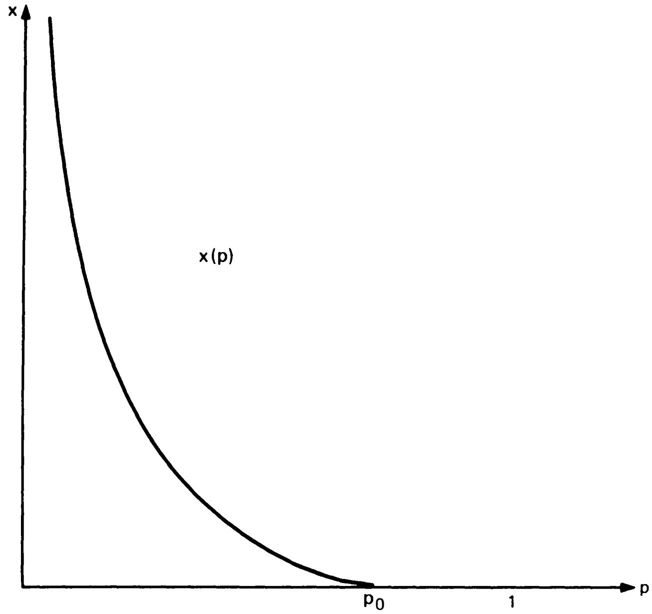
[2] If all parties are risk-neutral, the model can be generalized to any case in which expected accident costs are a product of functions of provider and consumer behavior. But some type of separability is crucial to the informational properties of the model, because the consumer must communicate his level of care to the provider through his insurance purchase decision alone. Since the insurance purchase is a one-dimensional variable, the parameter defining the level of care must be one-dimensional as well.

[3] In this situation only one consumer need be modeled, because from the firm's point of view, each consumer is handled separately.

[4] For instance, a manufacturer of bicycle locks insures lock owners against bicycle theft in the amount of $250. As efficiency requires, the firm plans to accompany higher quality locks with larger insurance policies.

[5] The model presented here was originally motivated as an attempt to construct an efficient mechanism for insuring consumers against electrical outages, but this application requires an extension of the provider-insurance mechanism to the public-good case.

FIGURE 1
COST OF REDUCING ACCIDENT PROBABILITY



$p \rightarrow 0$; $x'' > 0$ for all feasible p. All accidents are assumed to be identical. The function $x(p)$ is illustrated in Figure 1.

Let $y(q)$ be the cost to the consumer of limiting each accident-caused loss to q. We assume that the each accident-caused loss will be of the amount q_0 if no loss-mitigation measures are taken by the consumer, so that $0 < q \leq q_0$ and $y(q_0) = 0$. In addition, we assume that $y'(q_0) = 0$, $y' < 0$ for $q < q_0$, and $y'(q) \rightarrow -\infty$ as $q \rightarrow 0$, and that $y'' > 0$ for all feasible q. The function $y(q)$ is illustrated in Figure 2.

We define the social optimum to be the state in which total expected accident-related costs are minimized. We now calculate the behavior required to reach that state. The total expected value of accident-related costs is given by

$$C(p, q) = x(p) + y(q) + pq, \tag{1}$$

where pq is the expected value of losses caused by accidents. Therefore, the socially optimal accident-probability p^* and accident loss q^* are given by the solution of the following problem:

$$\underset{p,q}{\text{Min}}\ C(p, q). \tag{2}$$

Setting $\partial C/\partial p$ and $\partial C/\partial q$ to 0 yields the following first-order conditions for the social optimum:

$$x'(p) = -q \tag{3}$$

$$y'(q) = -p. \tag{4}$$

The properties of $x(p)$ and $y(q)$ guarantee that these equations have an interior solution.

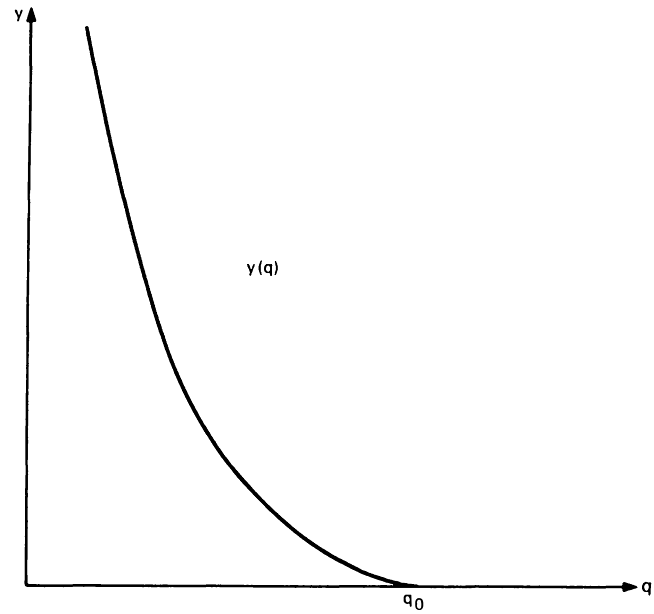
To insure that solution of (3) and (4) is a global minimum, we need require only that the function C is everywhere strictly convex. An additional condition, sufficient for convexity, is given by

$$x''(p)y''(q) > 1 \tag{5}$$

for all p and q. Experimentation with examples indicates that (5) is not very restrictive.

FIGURE 2

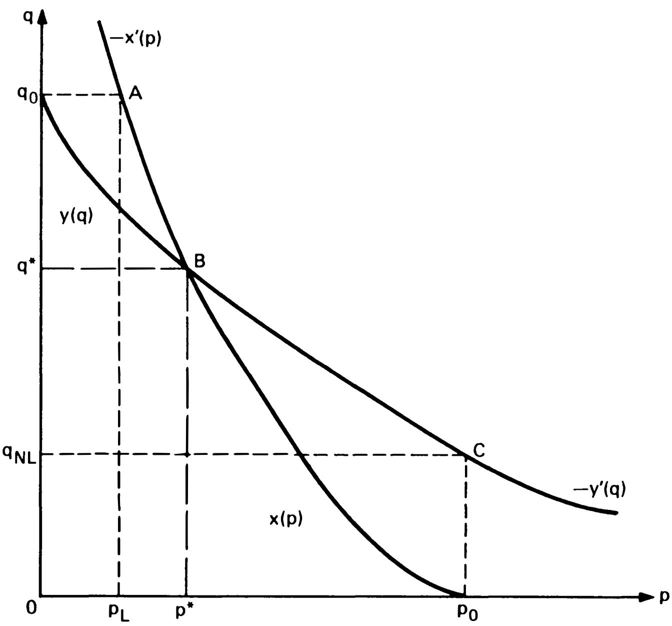
COST OF REDUCING CONTINGENT LOSS



If the functions x and y were known, these equations could be solved for p^* and q^*. This solution is illustrated in Figure 3.[6] The expected social cost associated with accidents is given by the area $0p_0Bq_00$. (The rectangle $0p^*Bq^*0$ is the expected cost of accidents,

FIGURE 3

THE EFFECTS OF ACCIDENT PREVENTION AND LOSS MITIGATION



[6] I would like to thank a referee for providing this ingenious diagram.

and the triangles p^*Bp_0 and q^*Bq_0 are the costs of accident prevention and loss mitigation, respectively.)

To implement socially optimal behavior by direct control, an agency would not only have to know the characteristics of the cost functions x and y, but would need to be able to monitor and enforce the desired levels of p and q as well. It is not likely that any regulating authority would be able to meet these conditions. Therefore, in this section we analyze behavior induced by methods requiring a lesser degree of agency information.

Generally, in the American economy, liability laws (and business reputation) are used to induce providers to take care in performing their services (Shavell, 1980). A strict liability rule requires the provider to reimburse fully the consumer for all costs incurred as a result of an accident, irrespective of fault. This removes most of the consumer's incentive to be careful (Oi, 1973). In the context of our model, a strict liability rule would permit the consumer to leave the cost of an accident at q_0, and the provider would be induced to adopt a relatively high measure of reliability, indicated by the accident probability p_L. The area q_0AB in Figure 3 indicates the extent of the excess welfare loss. In contrast to this situation, a total absence of liability rules would leave the consumer entirely responsible for losses. The excess welfare loss in this scenario is indicated by the area p_0CB in Figure 3. Most intermediate liability doctrines are deficient because the information required by the courts for their application is usually not available.

3. The purchased penalty system

■ To improve on the liability framework, we must search for a mechanism that requires a minimum of information, induces desired behavior on the part of the provider and the consumer, and is self-enforcing. Since appropriate provider behavior depends on potential consumer losses, any mechanism that approaches optimality must provide to the consumer a mode of expression by which he can communicate his loss function to the agency and the provider. The purchased penalty system, described in this section, is such a mechanism, but unlike provider insurance, it requires the rate-setting agency to be an independent regulator, capable of imposing fines on the provider.

The purchased penalty scheme allows the consumer to purchase an agreement that requires the agency to penalize the provider in the event of an accident. The agency offers the consumer a "menu" of proposed penalties indexed by v, the penalty type. The agency informs the consumer that if he purchases a penalty of type v, the provider will be induced to reduce the probability of accident to v. (As we shall see, this claim made by the agency turns out to be true.) When the consumer purchases a penalty of type v, he must pay a premium given by the schedule $r(v)$, and, in the event of an accident, the provider will be required to pay a penalty (fine) given by the schedule $f(v)$. This penalty is paid to the state; it is not received by the consumer. Both the premium $r(v)$ and the penalty $f(v)$ increase as v decreases, so that the more the consumer pays, the larger the penalty will be when an accident occurs. Presumably, if the consumer pays a large premium, the penalty imposed on the provider in the event of an accident will be large, so that the provider will have incentive to spend a considerable sum on prevention.

The extent to which this system induces desirable behavior depends on the premium and penalty schedules, f and r. We show that if the agency sets

$$r(v) = x(v) \tag{6}$$

and

$$f(v) = -x'(v), \tag{7}$$

then optimal behavior is induced. Note that the optimal size of the penalty to the provider is the marginal cost of reducing the probability of accident to the level v.

If the consumer purchases a penalty $f(v)$ with a premium $r(v)$, then the provider's expected-cost minimization problem is given by

$$\operatorname*{Min}_{p}\; x(p) + pf(v) - r(v).$$

Taking the derivative of this expression with respect to p, setting it equal to 0, and substituting the right-hand side of (7) for the left yield the equation $x'(p) = x'(v)$. Because $x'(p)$ is monotonically increasing, the obvious solution of this equation must be unique. The fact that x'' is everywhere positive implies that this equation is a sufficient condition for global optimality. If we let p_K denote the probability of accident set by the provider, we have

$$p_K = v. \tag{8}$$

In other words, this particular penalty schedule will induce the provider to set the accident probability at v, so that the agency's claim to the consumer will be borne out.

The consumer's cost minimization problem can now be written as

$$\operatorname*{Min}_{q,v}\; y(q) + r(v) + vq. \tag{9}$$

Given (6) and (8), this problem is equivalent to the social cost minimization problem, (2). Thus, the purchased-penalty mechanism leads to optimal provider and consumer behavior when the penalty and premium schedules are given by (6) and (7). Note that the functions f and r are dependent only on the provider's accident-prevention technology, as given by the function x. In structuring f and r, the agency need know nothing about the consumer.

4. Provider insurance

■ To make the purchased-penalty system practical, it must be combined with a system of insurance that leaves the consumer with little or no risk. Fortunately, this is not difficult to do. It is necessary only to change the rules of the purchased-penalty system to require that the consumer actually receive the penalty $f(v)$ as compensation for an accident, and at the same time to require that the consumer make an additional premium payment $vf(v)$ for this insurance. Put another way, to receive an insurance policy of type v, with indemnity $f(v)$ as defined by (7), the consumer must pay the premium $z(v)$, given by

$$z(v) = x(v) + vf(v). \tag{10}$$

The first summand is required as payment for the accident-prevention efforts that the consumer receives from the provider, and the second is the actuarial value of the insurance policy itself. It is important to understand that the consumer is not offered the opportunity to buy pure insurance; if he wishes to buy insurance, he must also buy accident-prevention services.

Given the existence of a risk-neutral entity and the absence of transactions costs, the solution to the social-cost minimization problem with a risk-averse consumer must be the same as that for the risk-neutral consumer with the addition that the consumer be fully insured. Thus, the first-order conditions for the social optimum are given by (3), (4), and

$$f = q, \tag{11}$$

where f is indemnity of the insurance purchased.

Will the behavior induced by the provider-insurance mechanism with a premium structure given by (7) and (10) lead to a social optimum? It is well known that when fair insurance is available, risk-averse agents will fully insure as social optimality requires. But because the provider-insurance mechanism offers a tied sale between accident prevention services and fair insurance, the standard arguments cannot be brought to bear. Nevertheless, as we now demonstrate, expected-utility-maximizing consumers will end up fully insured when the provider-insurance mechanism is structured according to (7) and (10).

Suppose that the consumer purchases the provider-insurance policy of type v. Then the provider will receive the premium payment $z(v)$ and knows that if an accident occurs, it will have to pay out the indemnity $f(v)$. Thus in minimizing expected accident-related costs, the provider will have to solve the following problem:

$$\operatorname*{Min}_{p}\; x(p) + pf(v) - z(v).$$

As is apparent from the almost identical problem solved in Section 3, the solution of this problem will be

$$p_I = v. \tag{12}$$

That is, the provider will invest in accident prevention under this provider-insurance regime so as to reduce the probability of accident to the parameter v.

For mathematical convenience, we represent the consumer's risk-averse sentiments with a strictly convex *disutility* function, $D(c)$, where c is the cost to the consumer of the insurance premium and any uninsured losses. Let $E(v, q)$ denote the expected value of disutility resulting from any particular consumer choice of v and q. That is,

$$E(v, q) = vD[y(q) + q - f(v) + z(v)] + [1 - v]D[y(q) + z(v)]. \tag{13}$$

Let (v_I, q_I) be a solution of

$$x'(v) = -q \tag{14}$$

$$y'(q) = -v. \tag{15}$$

Because of the assumed properties of x and y, we can be sure that (v_I, q_I) exists and is unique. By (7), (v_I, q_I) must also satisfy

$$f(v) = q. \tag{16}$$

We now show that (v_I, q_I) minimizes $E(v, q)$.

By the convexity of D, (13) yields

$$E(v, q) \geq D(v[y(q) + q - f(v) + z(v)] + (1 - v)[y(q) + z(v)])$$
$$= D(y(q) + z(v) + v[q - f(v)]) \tag{17}$$

for all (v, q), with equality when $q = f(v)$. Using (10) to simplify the right-hand side of (17), we get

$$E(v, q) \geq D(y(q) + x(v) + vq). \tag{18}$$

From the monotonicity of D and from the fact that (3) and (4) are solutions to (2), it follows that the right-hand side of (18) is minimized at (v_I, q_I), thereby satisfying (14) and (15). Because (v_I, q_I) satisfies (16), it follows that (17) and (18) must be equalities for (v_I, q_I). Hence, we have

$$E(v, q) \geq D(y(q) + x(v) + vq) \geq D(y(q_I) + x(v_I) + v_I q_I) = E(v_I, q_I)$$

for all (v, q), so that (v_I, q_I) minimizes $E(v, q)$.[7]

We now show that (v_I, q_I) is a social optimum. Using (12) and setting $f = f(v)$, equations (14)–(16) become the first-order conditions for the social optimum with risk aversion, given by (3), (4), and (11). Because (5) implies strict global convexity of the social welfare function, (14)–(16) are sufficient for the social optimum. We may now conclude, therefore, that in our model, provider insurance induces socially optimal behavior on the part of a risk-neutral profit-maximizing provider and a risk-averse expected-utility-maximizing consumer.

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[7] I would like to thank a referee for suggesting this tidy proof.

5. Provider insurance in a competitive industry

■ Suppose that the industry producing the underlying product or service is competitive and that there are many firms offering each type of provider insurance v. Firms are assumed to have identical total cost functions for production of the underlying product, $T(n)$, where n is the quantity produced. The average cost, $T(n)/n$ is assumed to be U-shaped. In addition to these costs, firms incur a cost of reliability given by $nx(p)$, where p, as before, is the probability of an accident. Without loss of generality, we assume that a single firm offers only one type of provider insurance. Let $s(v)$ denote the parametric price facing a firm that offers its output with insurance of type v. Each firm sets its output n and its reliability-level p to maximize profits. Profits for a firm are given by

$$\pi(n, p|v) = s(v)n - T(n) - nx(p) - pnf(v). \tag{19}$$

Solving the first-order conditions of profit maximization for p and $s(v)$ yields

$$p = v$$

and

$$s(v) = T'(n) + x(v) + vf(v).$$

In addition, $s(v)$ must satisfy a zero-profits condition, so that

$$s(v) = T(n)/n + x(v) + vf(v).$$

It follows that firms will set n to equate $T(n)/n$ with $T'(n)$. For this value of n, $T(n)/n$ is the minimum average cost of production and the competitive price of uninsured output. The price that must be imputed to provider insurance is therefore $x(v) + vf(v)$. But this is the value of the optimal provider-insurance premium given by (10).

We may conclude that the optimal structure of provider insurance is uniquely compatible with pure competition. Note that consumers need not observe the reliability of the output of the particular firm from which they are buying. They need to know only that p tends to be equated to v in the industry. The incentives created by provider insurance will do the rest.

6. Conclusion

■ Is there a mechanism that can induce the provision of reliability in goods or services to minimize the expected costs of accidents? In this article we have examined ways of achieving this goal in an economically efficient manner. Most legal mechanisms, such as various liability rules, are either inefficient or have unrealistic informational requirements.

The provider-insurance mechanism, when structured according to rules developed in this article, will induce desirable behavior and requires relatively little information and control. Furthermore, provider insurance protects the consumer from the risks associated with accidents. In the context of profit-maximizing providers and expected-utility-maximizing consumers, the availability of properly structured provider insurance is consistent with a socially optimal equilibrium. The optimal provider-insurance mechanism can be imposed on a noncompetitive industry by regulators, but it can arise spontaneously in competitive industries and can be sustained.

References

→ CLARKE, E.H. "Multipart Pricing of Public Goods." *Public Choice*, Vol. 11 (Fall 1971), pp. 17–33.

EHRLICH, I. AND BECKER, G.S. "Market Insurance, Self-Insurance and Self-Protection." *Journal of Political Economy*, Vol. 79 (July/August 1971), pp. 623–648.

GROVES, T. "Incentives in Teams." *Econometrica*, Vol. 41 (July 1973), pp. 617–631.

OI, W.Y. "The Economics of Product Safety." *Bell Journal of Economics and Management Science*, Vol. 4 (Spring 1973), pp. 3–28.

SHAVELL, S. "Strict Liability vs. Negligence." *Journal of Legal Studies* (January 1980).

VICKREY, W. "Counterspeculation, Auctions, and Competitive Sealed Tenders." *Journal of Finance*, Vol. 16 (May 1961), pp. 8–37.