Articles

Injury Litigation and Liability Insurance Dynamics

PETER HUBER

Prices for some lines of liability insurance have increased sharply in recent years, even while the real amount of coverage provided has declined. What accounts for these changes? The large financial inertia inherent in the insurance business, forecasting errors repeated across the industry, and herd-like reactions among many insurers have made the market adjustments exceptionally abrupt. But the most likely underlying cause for the current crisis in liability insurance is the inexorable expansion in liability law.

INFLATION-ADJUSTED PREMIUMS FOR LIABILITY INSURANCE held steady or declined somewhat from 1980 through mid-1984. Most insurers also continued to pay steady annual dividends to shareholders. The price of liability insurance then increased sharply in 1985 and 1986. The cost of coverage for medical malpractice increased by more than 40 percent; general liability policies (which cover products involved in accidents) rose by more than 70 percent (*1, 2*). Rates increased by 100 to 200 percent for some municipalities, 200 to 300 percent for day-care centers, 50 to 1000 percent for toy manufacturers, and 200 to 400 percent for chemical manufacturers (*3, 4*). The longer term trends have been less dramatic but are all in the same direction. Nominal medical malpractice premiums, for example, rose more than 200 percent in the last decade, and considerably more for certain specialties in some states (*1*).

Even as prices rose, coverage shrank. Insurers backed away from "long-tail" policies that cover all accidents in a particular year and shifted instead to "claims made" policies, which cover a much narrower window of time. General liability policies that once covered pollution arising from "sudden and accidental" incidents no longer do. Liability insurance for pollution-related "toxic torts," asbestos removal, or the cleanup of chemical dumps is almost unavailable. Policy limits have also been dropping rapidly. In 1984 a major pharmaceutical manufacturer was likely to have somewhere between $200 and $400 million of excess insurance coverage; by the beginning of 1986, much more than $50 million in coverage was difficult to obtain, and the premiums for this greatly reduced coverage were higher than before. Insurers, in short, have grown increasingly unwilling to provide their core service, which is to spread the financial repercussions of low-probability, high-consequence risks in both space and time.

What accounts for these abrupt changes? The question has been the subject of intense and often acrimonious debate among lawyers, insurers, and both state and federal regulators.

The author is a senior fellow at the Manhattan Institute for Policy Research, New York, NY 10012.

System Elements

Insurance financing is inordinately complex in its detail, but the larger picture is fairly simple. An insurance company is a financial lake. The depth of the water is its "reserve," money in the bank or in other stable investments that is set aside for loss payments in the future. Shareholder equity and earnings retained from prior years, which typically represent about half of an insurer's net worth, add to the financial cushion. Premiums flow into the lake; claims payments, operating expenses, and profit flow out.

In steady-state operations, insurance companies might operate with minimal reserves. Certain government-funded insurance programs in fact do. Income from current policies covers current claims. Future claims will be covered (it is expected) by future premiums. But it would be irresponsible for a private insurer to operate in this way. Reserves are the insurer's bridge between payouts that will be required in the future on policies that were sold in the past. "Long-tail" policies sold today can give rise to insurer liabilities years into the future, and these policies require correspondingly large reserves. Reserves must be adjusted continuously to reflect the best current estimates of insurance commitments already made but not yet fulfilled. Prudent insurance practices thus dictate that the level of the lake must rise when the rate of outflow increases. This requirement gives the system some unexpectedly dynamic features.

An insurance company maintains not one but numerous lakes. First-party health insurance, medical malpractice coverage, product liability, and ordinary car accidents require four quite separate reservoirs. Different insurers offer different combinations of lines, and markets are competitive (*5*). Each line must therefore sustain itself independently. Premiums paid for car insurance cannot cover claims on childhood vaccines. Any analysis of trends that fails to differentiate among different lines in the same way that insurers themselves do is unlikely to arrive at an accurate explanation of why the pricing of particular lines has changed so sharply.

Particularly important is the distinction between "long-tail" and "short-tail" lines. First-party health insurance, for example, is short-tail. Claims on a 1986 policy will normally be made and paid that same year or early in the next. Third-party liability insurance can have a much longer payout period. A product-liability policy sold in 1986 may lead to claims only years or even decades later. The reserve lake must be correspondingly large. The "tail" on a policy can be defined as the half-life of a policy—the average time between when the policy is sold and when a claim against it is collected. A line with a 1-year tail requires reserves roughly equal to 1 year's premiums or payouts; longer tail lines require correspondingly larger reserves. Reserves for automobile accident insurance are typically one to two times annual premiums; for product liability about two to three times; for medical malpractice and pollution liability four to five times or more.

Premiums on policies sold supply the bulk of the inflow into the

insurance lake. Depending on the line involved, these may annually amount to about 20 to 100 percent of the lake's volume. A second source of inflow is rainfall—the income the insurer earns by investing its reserves in stocks, bonds, or other assets. Annual inflow from this source is typically 10 to 20 percent of current reserves, comparable to the prime interest rate. Except for the longest tail lines, investment income is thus comparatively small. At 10 percent rates of return, investment income exceeds premium income only for policies with a half-life exceeding about 7 years.

Water also leaves the lake along several different paths. Payment claims account for the largest outflow. For most policy lines, this river is only somewhat smaller (50 to 70 percent of premiums) than the premium river flowing into the lake. Administration and underwriting expenses may typically amount to about 30 percent of premiums. Profit paid out to shareholders is another source of outflow, but a comparatively tiny one—typically only a few percent of premiums.

The steady-state operation of such a system is simple enough. Premiums must match liability payments and administrative expenses (which can be viewed as a single stream of "claims paid"), with an appropriate, usually modest, discount for investment income. Insurance for all but the longest tail lines is thus primarily a business of balancing premium inflow against claims paid.

How does such a system respond to perturbations in either liability claims or investment income? Fluctuations that are much shorter than the policy half-life are simple: they need not concern the insurer at all, so long as they average out to zero. At the other extreme, fluctuations that occur over much longer periods will be cleanly mirrored in premium inputs, with little distortion. The most interesting perturbations are those that occur over time scales comparable to the half-life of the policy. Markets for insurance policies with 5-year tails are most likely to resonate to external stimuli that vary over comparable periods.

Consider a change in the legal rules that triggers an increase in liability payouts rising steadily over a period of years. An insurer with perfect foresight will simply adjust its premiums in a mirror-image transient several years earlier. The insurer's lead time here must equal the half-life of the policy. In the intervening years, reserves will gradually rise. The insurer's profits should not change significantly, at least not as a fraction of premium income.

A transient that reduces investment income, instead of increasing payout rates, will have qualitatively similar effects. Insurers with perfect foresight will raise premiums in advance of declining investment prospects, this time to reflect the time gap between when a policy is sold and investment income is earned. Perfect foresight is somewhat easier here. Only half the lake, on average, separates the premium from the investment income it will generate, whereas the entire lake separates the premium from the payout.

But perfect foresight of any kind is difficult to come by. Real-world insurers must sell long before they know the exact cost of the goods sold. Suppose an insurer discovers one day that a previously unanticipated (but now wholly obvious) trend toward higher liability payouts is under way. Premiums must be adjusted upward immediately, and in a step that looks forward to likely payout rates not tomorrow but several years hence. Prudent underwriting also requires an immediate boost in reserves—policies already written over the last several years, the insurer now recognizes, have been sold too cheaply, and the line is underreserved. The overall ledger can be kept in balance only with an immediate, singular, downward adjustment in shareholder profit or surplus. Once again, unanticipated transients in investment income can have similar effects.

A simple dynamic analysis thus suggests that unanticipated changes in either investment income or in liability payouts can have qualitatively similar impacts on premiums. This is not to say, however, that changing payouts and changing investment revenue are, or have been, quantitatively equal in forcing changes in rates.

Investment Income

When interest rates are high and profits healthy, insurers can cut their rates, and must do so or sacrifice their sales to competitors. In the early 1980s, competing liability insurers, eager to take advantage of high interest rates, cut premiums and embarked on something of a price war. The industry as a whole sold more insurance but at lower unit prices. In the period from 1980 to 1983, total premium revenues for general liability actually decreased slightly (*6*). In retrospect it is now clear that many insurers overestimated future investment income. Some part of the recent sharp increases in premiums can thus be attributed to the compressed premium adjustments made when adverse economic trends were belatedly recognized. Other factors suggest, however, that undue optimism about investment possibilities in the early 1980s was not the dominant factor at work here.

One striking point is that there is no crisis—real, contrived, or imagined—in most lines of insurance other than certain long-tail liability and casualty lines. Auto liability, workers' compensation insurance, fire, and commercial health, and most lines of property insurance remain readily available and have generally not been marked by the sharp price increases and contraction in coverage typical of some of the more publicized liability lines. The total dollar volume of premiums written on nonliability and short-tail lines has increased much less sharply than the written premium volume for liability lines. Life insurance is also readily available and stable in price. Perhaps all of the more stable lines have tails that are either too long or too short to resonate to business cycles important for the liability lines. The fact remains that the most severe premium shocks have occurred only in certain lines of liability insurance and nowhere else.

The premium shocks have also apparently been selective by country. The sharp increases in the cost of liability insurance, and the equally sharp reduction in the amount of coverage actually provided, are events peculiar to the United States. Ontario, Canada, has experienced some similar short-term insurance difficulties, but it also has unusually liberal liability standards. Insurance in the rest of Canada has been adversely affected by the fact that international reinsurers treat North America as a single market. No other Western industrialized country has experienced changes even roughly comparable in size to the recent shocks in the United States. Many of the most important business cycles, however, are common to all. Financial markets, and much insurance underwriting, are also international in scope. Indeed, reinsurers in London and Tokyo have shouldered a substantial fraction of recent losses attributable to U.S. payouts. Liability insurers in other countries have thus had occasion to make similar underwriting and investment mistakes as U.S. firms, and to pass on the costs of those mistakes to policy holders. The underwriting mistakes have indeed been international in their scope, but the premium shocks have been largely focused on particular lines of U.S. liability insurance.

Injury Litigation Trends

Reliable and meaningful data on liability payouts are difficult to obtain. Insurance companies are reluctant to share the information, because actuarial insight and experience are what gives an insurer the edge on competitors. Average claim and settlement figures are also strategically important pieces of information in litigating and set-

tling future claims. Nonetheless, the larger and longer term trends in payouts are unambiguous.

Liability rules enforced by the courts have been changing steadily during the past 30 years, and the direction has consistently been toward broader liability. Modern product-liability law crystallized around a first handful of landmark rulings in the 1960s, and a second set in the 1970s, which permitted juries to hold liable the manufacturers of cars, consumer products, and then even of vaccines and therapeutic drugs, for defects in "design" of the product itself or the warning accompanying it (*7*). "Discovery" rules have greatly extended the periods during which claims can be filed; claims arising from medical malpractice, drugs, or toxic chemicals now stretch decades or even generations after policies were written and the harmful contact occurred. Notably more generous liability standards for products have gradually loosened the standards applied against service providers such as doctors, more through changes in legal culture than in black-letter law. Liability law mushroomed in the late 1970s and early 1980s, with asbestos and the Dalkon Shield cases, a proliferation of punitive damage awards, the rapid expansion of awards for "pain and suffering," and the creation and rapid expansion of the "toxic tort." Overall, more suits have been filed, and average awards and settlements have grown.

The volume of litigation, to start with, has increased markedly in certain lines. Litigation against manufacturers of cars and countless other simple consumer products mushroomed in the late 1960s. Seminal judgments against manufacturers of vaccines and contraceptives triggered an avalanche of suits against these products a decade later. Employees injured on the job have successfully developed and used new theories for suing suppliers of equipment and materials such as asbestos companies. As a result of such changes, product liability cases initiated in federal district courts grew from 6,132 in 1979 to 13,554 in 1985, an average annual litigation growth rate of 20 percent (*8, 9*).

The number of personal injury lawsuit filings between private parties in federal courts has risen more than 50 percent, to about 32,000, just since 1980 (*10*). The rate of medical malpractice suits filed against physicians increased from 2.5 per 100 in 1976 to 16 per 100 in 1984 (*11, 12*). Claims filed against physician-owned companies increased by more than 120 percent in the 4 years beginning in 1979 (*3*, p. 45). A survey of 1200 local governments found that claims against municipalities increased by 140 percent between 1979 and 1983 (*3*, p. 47). In New York City, for example, there was a 375 percent increase from 1977 to 1985 in personal injury claims (*3*, p. 47).

Inflation-adjusted average awards have also been rising inexorably. In one study, in which average liability judgments in cases that went to trial in Cook County, Illinois, during the periods 1960 to 1964 and 1980 to 1984 were compared, showed a real growth rate of about 7 percent a year (*13*). The average real growth rate in claims paid by insurers (including the large fraction of cases that are settled) has been about 2.4 percent since 1967. The inflation-adjusted average growth rate in liability compensation paid per claim between 1981 and 1986 was about 5 percent per year for auto claims and 8 percent per year for other tort claims. A small fraction of unusually large claims account for part of the increase in average awards, but median awards have also steadily outpaced inflation in this period.

Both the number of liability cases filed and the average size of awards and settlements have thus increased steadily. These have produced a continuous—and still sharper—increase in insurance payouts. Often cited in this regard is the experience of self-insured New York City. New York paid out $150 million in 1985, almost all for liability claims, and this was about twice what the city paid in 1983 (*14*).

One must emphasize, however, that the broad averages conceal as much as they reveal. Forty percent of all tort suits involve routine car accidents, an exceptionally stable area of both liability law and insurance in recent years. The dramatic increases in insurance rates have been selectively focused on particular lines. Those lines closely track the areas of liability law that are expanding most rapidly.

Personal injury litigation involving contraception, pregnancy, childbirth, and childhood vaccines, for example, can and increasingly does result in extremely large awards. Dramatic increases in insurance rates (to the point of outright unavailability of coverage at any price) have correlatively been directed at contraceptives, morning sickness drugs, obstetricians, and day-care centers. Municipalities and other government entities have recently proved particularly vulnerable to the principle of "joint-and-several" liability, which can require a defendant with minor responsibility for a particular accident to shoulder its full costs. [Awards in municipal liability lawsuits, on the average, rose from $230,000 in 1982 to $2 million in 1985 (*15*).] Government entities have likewise been hit particularly hard in the latest round of insurance increases. Both joint-and-several liability and liberal evidentiary standards on questions of cause and effect have recently made all defendants that handle chemical toxins unusually vulnerable to liability suits. Recent drastic adjustments in rates for "environmental impairment liability" insurance have again mirrored an earlier revolution in the legal realities.

Under any model of the insurance process, increasing payouts must translate into higher premiums. A second, less obvious but perhaps equally important effect of increasing payouts derives from "adverse selection" by those insured. The successful operation of an insurance pool depends critically on the insurer's ability to attract low-risk customers into the pool (*16*). When average insurance rates rise, low-risk customers have an increasingly strong incentive to opt out, either completely or by relying on higher levels of coinsurance. An exodus also spurred by increases in the variance of risk within any particular insurance pool—the larger the spread of risks, the more unattractive the rates are for the lower risk members. The departure of its best customers forces the insurer to raise premiums further, which may encourage still more departures by customers that the insurer can least afford to lose. In extreme cases this process becomes unstable—only the highest risks remain in the pool, and insurance rates rise toward the policy limit. One must suspect that the adverse selection dynamic has been strongest in lines covering such things as medical malpractice, municipal liability, pharmaceuticals, vaccines, and contraceptives, where average payouts have been rising rapidly and very wide variations in awards have been common.

Whether driven by the direct effect of adverse trends in the courts, or the indirect process of adverse selection, insurance company payouts on liability policies have grown rapidly in recent years, from about 5 to 15 percent per year, depending on the line, after adjustment for inflation (*17*). The sharpest insurance rate increases have generally occurred in lines where liability standards have been the most volatile. The actual payout histories available to date may be modest, as has been the case, for example, with day care centers or childhood vaccines. But the possibilities for enormous awards under fast-changing legal standards are beyond dispute. Insurers, for the most part, appear to have adjusted their rates accordingly.

Reserves

If a sudden and heretofore unexpected change in legal rules promises a steady, 7 percent annual growth rate in inflation-adjusted payouts on a particular line over the next 5 years, and the policy half-life is itself 5 years, the insurer must immediately boost premium

rates more than 40 percent. The insurer must also immediately increase reserves by about 20 percent. Reserves on a line of this type will likely amount to about 5 years of premiums; the insurer must therefore also locate immediately another year's worth of premiums to boost reserves. In a competitive market the deficiency will have to come from shareholder equity or profit. In a less than perfectly competitive market some attempt might be made to recoup the charge by further increases in current premiums unrelated to true costs.

In recent years, insurers have indeed been boosting their reserves significantly. In 1986, for example, the CIGNA Corporation made a $1.2-billion charge against its fourth-quarter 1985 earnings to strengthen its reserves. Of this $1.2 billion, $220 million was for professional liability losses, $120 million was for asbestos losses, and approximately $300 million was for the liability portion of commercial package policies. Interestingly, one-sixth of the adjustment was for pre-1978 business. The increase was equivalent to 28 percent of CIGNA's year-end 1984 reserves (*18*).

Many other insurers have made similar adjustments. Industry-wide data on the general liability and medical malpractice lines at the end of 1984, for example, suggested serious reserve inadequacies; all trends suggested that the original loss reserves were insufficient and that the deficiency was growing (*6*). In early 1985, reserve deficiencies were estimated as high as 25 to 30 percent for the general liability line and about 20 percent for the medical malpractice line (*19*). Data for 1985 indicated a general return toward healthier reserve levels, suggesting that many insurers had taken a hard look at their reserving practices, the core of their business function. Though some critics of the industry charge otherwise, the overwhelming consensus among financial analysts is that many liability lines have been underreserved in recent years, and a good number remain at least 10 percent underreserved today (*17*).

Profits

Whatever the level of the insurer's prescience, insurance is a forward-looking business. Policies are priced prospectively, not retrospectively; insofar as premiums are concerned, the past is relevant only in that it may be a harbinger of the future. On a typical, long-tail line, today's premiums must reflect liability awards 5 years hence, not 5 years ago. The difference is significant when inflation-adjusted payouts are growing steadily.

The past can, however, directly affect an insurer's current profits. In a competitive market, insurers cannot adjust current premiums to make up for past errors in projecting either investment income or liability payouts. If the payouts turn out to be higher than projected, or investment revenues lower, shareholders lose.

The profitability of the insurance industry has recently been the subject of intense debate (*20*). Nonetheless, the year-to-year profitability of insurance companies is not one of the most useful measures of the condition of the insurance industry and is almost valueless in either justifying or attacking recent sharp premium increases on particular lines. Annual insurer profits on liability lines depend primarily on the small difference between two large numbers—the actual level of the reserve lake at the end of an accounting period, and the estimated level at which the lake should be to cover future liabilities on policies already sold (*17, 21*). The second figure is highly uncertain, which means that the profitability picture is many times more so. Indeed, insurers fight incessantly with the Internal Revenue Service on one flank, which argues for lower reserves and therefore higher short-term book profits and taxes, and with state insurance commissions on the other, which demand higher reserves for prudent underwriting.

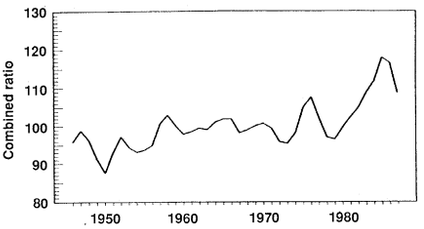

Fig. 1. Aggregate combined ratio trends for U.S. liability insurers. The combined ratio consists of payments, policyholder dividends, reserves, and claims adjustment expenses for losses incurred in a given year as a ratio of premiums earned in that year added to the ratio of operating expenses to written premiums. A combined ratio of over 100 means that more money was paid out and put aside for future payments than was taken in as premiums. Investment income aside, the combined ratio measures the insurance industry's underwriting results (*2, 32*).

With this well in mind, one may note that liability insurers' profit pictures in 1984 to 1986 did in fact include adjustments of a kind that could be linked to unduly optimistic earlier projections of either losses or investment income. In 1984, the U.S. property and casualty insurance industry reported a net operating loss of $3.8 billion—the worst industry performance since 1906, the year of the San Francisco earthquake (*22*). The heavy losses continued in 1985. Insurer profitability on these lines has been largely restored, by the straightforward expedient of drastically lowering coverage and raising rates. It seems unlikely that insurers, who understand the basic hydrology of underwriting as well as anyone else, will soon repeat their recent mistakes. This probably also explains why insurer stock prices have been stable or rising in recent years.

The Insurance Cycle

Much has been made of the "insurance cycle," particularly by those eager to find an explanation for recent rate shocks outside the liability system (*23*). The liability insurance industry experienced a small slump in 1969, for example, a larger one in 1975, and a still larger one in 1985 (Fig. 1). The increases in liability insurance rates following each slump also grew progressively larger. Until the most recent shocks, the accepted wisdom was that liability insurance underwriting had a natural cycle of about 6 years (*24*).

In normal markets, both supply and demand are reasonably elastic. Any external factors that perturb the equilibrium between supply and demand are thus cushioned by the moderate responses of both suppliers and consumers. Insurance markets may well be badly behaved on both sides of this picture. Capital markets are very fluid, so that changes in either actual costs (or, because insurance is forward-looking in predicted costs) may trigger unusually large swings in supply. Typical consumers of insurance, by contrast, are likely to be rigid in their insurance needs, so that swings in demand provide little help in smoothing out swings in supply. These factors may combine to make liability insurance markets quite volatile and cyclical. According to the most familiar explanation of this phenomenon, capital flows into insurance markets in bullish times, but demand for insurance stays constant. Rates are therefore cut sharply, and competition can be intense. In the following half of the cycle the trends are reversed (*24, 25*). Periods of optimism and pessimism may of course be triggered by external factors, such as the abnormally high interest rates in the early 1980s.

This scenario may possibly explain why business cycles in the insurance business are particularly pronounced, but it does not explain what perturbations trigger this cycle in the first place or why our understanding of the cycle does not itself suppress it through ordinary market forces. One suggestion has been that specialty

insurers, often in the form of captive companies owned by nonprofit associations, are prone to rush unwisely into the market during the upswing of the cycle, depressing price below true cost by underestimating future payouts or overestimating future investment earnings (*17, 26*). Another suggestion is that the forecasting methods used by insurance rating bureaus may help to sustain the cycles (*27*). A third possibility is that newcomers to the insurance business with fewer sunk costs and less shareholder equity may periodically depress prices below cost because they are more willing to gamble against the risk of their own default (*28*). Yet another is that insurance companies are prone to make large but essentially random errors in forecasting future losses, which then trigger sharp adjustments because of the financial inertia inherent in the insurance process (*17, 27–28*).

All of these explanations may be right in part, but the last and least elaborate is also the most convincing. Deterministic cycles inherent in the industry's structure have undoubtedly played a role in recent increases in some insurance rates. It is more difficult, however, to explain why the cycle should have been felt in the United States but not abroad, and primarily in U.S. liability lines, and not in first-party insurance of any type. In any event, the steadily escalating amplitude of the insurance cycle in recent decades must surely be attributed to successive attempts by the industry to adjust belatedly to increases in payouts.

The outstanding question, and also the most difficult to answer, is how so many insurers have managed to make similar mistakes—followed later by similarly abrupt corrections—in such close synchrony. Herd psychology, both bullish and bearish, appears to play an important role here, as it does in many other financial markets. Herd instincts among insurers are undoubtedly sharpened by the fact that insurers share a considerable amount of rate and loss information. Insurers also share seats of the various committees of the Insurance Services Office, an organization that promulgates advisory rates and policy terms for many lines. Finally, the insurance industry enjoys certain exemptions from antitrust supervision by the Federal Trade Commission. Liability insurance is an information-intensive business, and for that reason it is unclear whether the sharing of loss information and the standardization of insurance forms undercuts competition or promotes it. But all of these factors may encourage collective error in projecting the future of both liability law developments and investment prospects; they may likewise promote simultaneous adjustment when errors are recognized. And as we have seen, error in either type of projection eventually requires sharp correction in rates, at least on longer tail lines.

Conclusion

Whether or not insurers are prone to consciously parallel action, the modest, though surprisingly controversial, conclusion must be that liability insurance rates depend primarily on the liability rules that create a need for such insurance in the first place (*29*). Rapid increases in rates derive largely from the most obvious source—unexpected increases in payouts, amplified by the large reserves that must be carried for long-tail lines.

The link between rates and payouts is obvious when the insurance market operates at steady state. Nothing peculiar to the transient dynamics of insurance markets fundamentally changes that link. A healthy insurance system has, and is intended to have, a large financial inertia. Not only current rates but also accrued reserves must quickly be adjusted to reflect new legal realities. In a world of imperfect foresight, insurance reserves therefore amplify the short-term impact of both business cycle and legal system transients on the premiums charged to policyholders. But even for the longest tail liability policies commonly written, transient changes in the legal rules have a very much larger impact on premiums than transients in the business cycle.

Capping liability payouts has had some demonstrable impact in the few instances where strict rules have been put in place. One study showed that states adopting caps on awards in medical malpractice cases have experienced an average 20 percent decrease in average claim size 2 years after adoption (*30*). Indiana placed severe caps on medical malpractice awards in 1975; by 1985, premium rates for certain classes of medical malpractice risks were 30 to 50 percent lower than those in neighboring Illinois, Michigan, Ohio, and Kentucky (*31*). Other initiatives in recent years have had little visible impact, however. Predicting claims reductions on the basis of modest changes in the law is no easier than predicting increases, and most insurers are taking a wait-and-see attitude toward legislation of this type.

Insurance is a fundamentally predictive business. Even under conditions of monopoly—which do not in fact prevail in this country—rational insurance pricing policies will look to future levels of demand for insurance, not to past costs of policies already written. Rational insurers do not set rates "to recoup past losses," and they cannot do so in any reasonably competitive market. They set rates in expectation of future claims and returns on investment in the interim. Few students of the liability system are predicting that claims and awards will soon stop rising; almost none expect any decline in awards, absent very decisive legislative intervention which does not appear to be forthcoming. More liability brings about higher premiums for liability insurance. Imperfect foresight coupled with the financial dynamics of insurance often means that the upward adjustments are made uncomfortably abruptly.

REFERENCES AND NOTES

1. J. S. Todd, testimony at hearings before the Senate Committee on Commerce, Science and Transportation, 99th Cong., 2nd sess. (4 March 1986), p. 228.
2. P. Wish, "Review and preview: Up from the ashes," Best's Review, Property Casualty Insurance Edition (A. M. Best, Oldwick, NJ, January 1987), p. 90.
3. U.S. Department of Justice, "Report of the Tort Policy Working Group on the causes, extent and policy implications of the current crisis in insurance availability and affordability" (Washington, DC, February 1986), pp. 8–12.
4. Chemical Manufacturers Association, statement in (*1*), p. 263.
5. P. Joskow, *Bell J. Econ. Management Sci.* **4**, 375 (Autumn 1973); U.S. Department of Justice, "Federal-state regulation of the pricing and marketing of insurance" (Government Printing Office, Washington, DC, 1977).
6. *Best's Casualty Loss Reserve Development* (A. M. Best, Oldwich, NJ, 1986).
7. For example, Henningsen v. Bloomfield Motors, 32 N.J. 358, 161 A.2d 69 (1960); Greenman v. Yuba Products, 59 Cal. 2d 57, 27 Cal. Rptr. 697, 377 P.2d 897 (1963); Larsen v. General Motors, 391 F.2d 495 (8th Cir. 1968); Reyes v. Wyeth Laboratories, 498 F.2d 1264 (5th Cir. 1974).
8. Conning & Company, "Crisis in liability insurance—a time for change" (Hartford, CT, November 1985), p. 11.
9. A. Maisonpierre, testimony at hearings before the Senate Committee on Commerce, Science and Transportation, 99th Cong., 2nd sess. (19 February 1986), p. 107.
10. Bureau of Justice Statistics, "Bulletin: The federal civil justice system" (U.S. Department of Justice, July 1987), p. 4.
11. M. J. Mullen, in (*1*), p. 183.
12. H. Manne, *Medical Malpractice Policy Guidebook* (Florida Medical Association, Jacksonville, FL, 1985); American Medical Association Special Task Force on Professional Liability and Insurance, "Professional Liability in the '80s, Reports I and II" (American Medical Assoc., Chicago, October and November 1984).
13. J. Kakalik and N. Pace, "Cost and compensation paid in tort litigation" (Rand, Santa Monica, CA, 1986); M. Peterson and G. Priest, "The civil jury: Trends in trials and verdicts, Cook County, Illinois, 1960–1979" (Institute for Civil Justice, Santa Monica, CA, 1986).
14. J. Angoff, in (*9*), p. 80.
15. D. M. Farmer, testimony at the hearings before the Subcommittee on Business, Trade and Tourism of the Senate Committee on Commerce, Science and Transportation, 99th Cong., 1st sess. (3 December 1985), p. 147; A. Chin and M. Peterson, "Deep pockets, empty pockets: Who wins in Cook County jury trials" (Institute for Civil Justice, Santa Monica, CA, 1985).
16. G. Priest, "Modern tort law and the current insurance crisis" (Working paper 44, Yale Law School, Program in Civil Liability, New Haven, May 1986).

17. S. Harrington, "Prices and profits in the liability insurance market" (paper presented at the Brookings Institution Conference on Legal Liability, Washington, DC, 15 June 1987).
18. J. Greenwald, *Business Insurance*, vol. 1 (10 February 1986).
19. On-Line Reports, Best's Review, Property/Casualty Insurance Edition (A. M. Best, Oldwick, NJ, February 1985).
20. For views at the poles, compare Insurance Services Office, in (*22*) and Insurance Services Office, "Insurer profitability: A long-term perspective" (New York, NY, 1987), with National Insurance Consumer Organization, "And now the real facts: A response to the Insurance Services Office's 'Insurer Profitability: The facts'" (Alexandria, VA, undated).
21. G. Gottheimer, in *Crisis Avoidance: Insurance Responsibilities*, N. Williams, Ed. (Society of Chartered Property & Casualty Underwriters, Malvern, PA, 1986).
22. Insurance Services Office, "Insurer profitability—the facts" (New York, NY, February 1986); Insurance Services Office, "1985, a critical year: A study of the property-casualty insurance industry" (National Association of Independent Insurers, New York, NY, May 1985).
23. R. Hunter, "Taming the latest insurance 'crisis'," *New York Times* (13 April 1986), p. F3; "The manufactured crisis: Liability-insurance companies have created a crisis and dumped it on you," *Consumer Reports* (August 1986), p. 544.
24. For example, B. Stewart, in *Issues in Insurance*, J. Long, Ed. (American Institute for Property and Liability Underwriters, Malvern, PA, 1981), vol. 2, p. 79.
25. Some studies have suggested that the cycle timing and amplitude may vary by line, for example, Conning & Company, "A study of why underwriting cycles occur" (Hartford, CT, 1979).
26. R. McGee, *Fed. Reserve Bank NY Q. Rev.* **11**, 22 (Autumn 1986).
27. E. Venezian, "Ratemaking methods and profit cycles in property and liability insurance," *J. Risk Insurance* **52**, 477 (September 1985).
28. Munch and Smallwood, *Bell J. Econ.* **11**, 261 (Spring 1980); J. Finsinger and M. Pauly, in *Risk and Capital*, G. Bamber and K. Spremann, Eds. (Springer-Verlag, New York, 1983).
29. New York Governor's Advisory Commission on Liability Insurance, "Insuring our future" (Albany, NY, 7 April 1986).
30. P. M. Danzon, "The frequency and severity of medical malpractice claims" (Rand, Santa Monica, CA, 1982).
31. Alliance of American Insurers, American Insurance Association, National Association of Independent Insurers, "Property and casualty insurance industry data and the case for tort reform" (Schaumburg, IL, June 1986).
32. I am indebted to B. Mathew for excellent research assistance in the preparation of this article.

The Use of a Charge-Coupled Device for Quantitative Optical Microscopy of Biological Structures

YASUSHI HIRAOKA, JOHN W. SEDAT, DAVID A. AGARD

The properties of a charge-coupled device (CCD) and its application to the high-resolution analysis of biological structures by optical microscopy are described. The CCD, with its high resolution, high sensitivity, wide dynamic range, photometric accuracy, and geometric stability, can provide data of such high quality that quantitative analysis on two- and three-dimensional microscopic images is possible. For example, the three-dimensional imaging properties of an epifluorescence microscope have been quantitatively determined with the CCD. This description of the imaging properties of the microscope, and the high-quality image data provided by the CCD, allow sophisticated computational image processing methods to be used that greatly improve the effective resolution obtainable for biological structures. Image processing techniques revealed fine substructures in *Drosophila* embryonic diploid chromosomes in two and three dimensions. The same approach can be extended to structures as small as yeast chromosomes or to other problems in structural cell biology.

OPTICAL MICROSCOPY (OM) IS A POWERFUL YET STILL underexploited approach for analyzing biological structure and function at the cellular level. Biological specimens can be examined in an aqueous, defined ionic environment under nonperturbing conditions and in many cases in the living state. Also, OM techniques are extremely rapid and permit many samples to be examined under a wide variety of conditions. Especially since the advent of specific probes such as monoclonal antibodies, cloned DNA sequences, DNA-specific dyes, and calcium and *p*H-dependent fluorophores (*1, 2*), cellular organization can be explored with high selectivity. Large cells, specific tissues, or, as in the case of *Caenorhabditis elegans* (*3*), whole organisms can be analyzed by OM.

Although biological samples are intrinsically three-dimensional, traditional OM methods have provided only a two-dimensional (2-D) representation of the three-dimensional (3-D) organization; also, the analysis is generally not quantitative. To overcome these limitations, we have been developing 3-D data collection methods for OM in conjunction with powerful image-processing techniques (*4–6*) to examine biological structures at the cellular level. We investigated the 3-D organization of interphase chromosomes initially with *Drosophila melanogaster* polytene chromosomes as a model system (*4, 6–8*). Optical section data in digital format was computationally processed (*6*) to remove the out-of-focus information that contaminated each image plane. The resultant 3-D image was analyzed by computer-aided modeling to reveal the spatial arrangements of the chromosomes within the nucleus (*9, 10*). This was followed by an analysis of the 3-D structures (*6–8*) as a function of transcription patterns, cell type, and developmental stage.

We recently extended these studies to the high-resolution analysis of *D. melanogaster* embryonic diploid chromosomes, which have a nuclear diameter that is 1/10 that of the polytene chromosomes. To reconstruct a 3-D image at a resolution approaching the diffraction limit of an optical system, it is critical that the out-of-focus

The authors are at the Department of Biochemistry and Biophysics and the Howard Hughes Medical Institute Structural Biology Unit, University of California San Francisco, San Francisco, CA 94143-0448.